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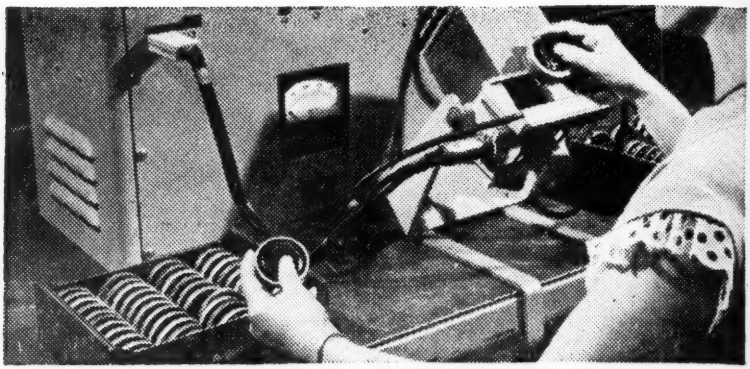

This Western Electric employee mounts a transmitter in the test fixture which is swung down to free an artificial mouth at 45-degree angle, just as transmitters are held in use. More than a million transmitters are tested each year.

This mouth speaks to millions

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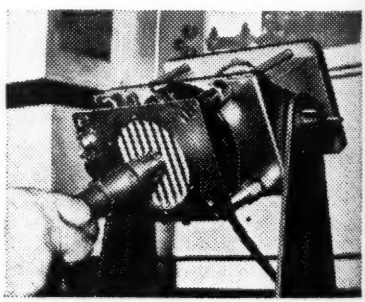

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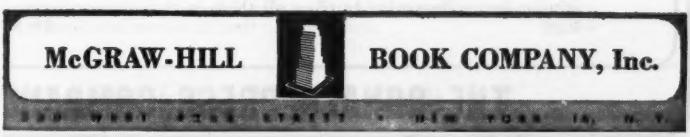

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Engineering Planning

By HAROLD S. OSBORNE

Chief Engineer, American Telephone and Telegraph Company

Last year in speaking to this group on the general question of engineering education and the requirements of industry, I remarked that the young engineer as he comes into industry generally has little conception of what is involved in carrying out the broad range of engineering studies which can be described as engineering planning. My assignment today is to enlarge on that remark and discuss the possible relation of engineering planning to the curriculum of the engineering school.

What is Engineering Planning?

It seems desirable first to outline what is meant in this discussion by the term "engineering planning." This seems particularly necessary because the word "planning" is very widely used, and even abused, in relation to a great deal of human activity in all fields of work.

Engineering plans are of many types. While no classification can be cleancut, I think it is helpful in our discussion to name and define a few distinctly different types.

First there is the type of plan which consists of detailed specifications of a specific object or a type of object to be constructed. Examples of this are the specification for an electric generator or the plans and specifications of a building. Following Mr. Chester Barnard's terminology I will call this the "explicit" plan.

Young graduates of engineering schools are generally familiar with this type of plan—it is closely related to their college work and they have an appreciation of the need for it and the problems involved.

The next classification we will call the "project" plan. It relates to a complex of jobs which are involved in one project and to the inter-relations between these parts of the project. It often includes a number of explicit plans.

An illustration of the project plan which is common in the telephone field is the replacement of a manual central office with a dial central office. This often involves the selection and purchase of a site, the design and construction of a building designed to meet the special technical needs of the case, the selection of the type of dial central office equipment to be used, the specification in detail of the quantities, types and interconnection of a large variety of equipment units, the design of the floor plan layout, arrangements for the provision of power including usually both commercial power and an emergency engine driven generator set, the design and installation of conduits and telephone cables to connect to the new equipment the telephone lines which are to be served, the changing of telephone sets or the installation of dials for all customers of the area, the instruction of customers in the new method of operation, the issuance of a new directory, provision for the future of operators who no longer will be needed at this location after the change to dial operation, and the employment and training of the additional

* Presented before a joint meeting of the Electrical Engineering and Industrial Engineering Division at the ASEE Annnal Meeting, East Lansing, Michigan, June 26, 1951.

men necessary to carry out the work involved in the project and to maintain the new building and equipment in normal service. Very often a project includes also the provision of new means for handling toll messages and new terminations for toll lines. Underlying and preceding all of this work are the necessary studies to determine that the project is a desirable one from the standpoint of service, economy and the general development of the telephone system in that area, the best general location of the proposed new office and the time when the job should be done.

This project includes a considerable number of interrelated explicit plans. It involves an intimate correlation between all of these explicit plans to form an organic whole. When the project is carried out it involves also a close coordination of timing of a wide variety of jobs done by different groups of people.

Illustrations of the project plan could be multiplied in all fields of engineering work.

A third type of plan may be called the fundamental plan. This type of plan is more far-reaching and forward-looking than the project plan and correspondingly far less explicit. It expresses the best picture which can be prepared at this time of the future design of a plant or operating system. It is intended to crystallize the goal toward which current projects should be directed and to be used as a base of reference in the design of all such projects. It is often of great importance in determining the future adequacy and financial health of the entire enterprise.

An illustration of a fundamental plan is given in a paper presented last January at the A.I.E.E. Winter Meeting by several engineers of the American Gas and Electric Service Corporation. This paper described the proposed 315-kilovolt transmission system of the American Gas and Electric Company. Looking forward it was recognized that the present 132-kilovolt network in Ohio, Indiana, and adjacent states would become inadequate. Extensive researches in the economies and problems of the use of higher voltages led to the selection of 315 kilovolts as the best level for the new transmission system. Plans were then made of the points which should be interconnected by the new high voltage system, the tower and conductor design, number of circuits on each route, interconnection with the rest of the system and all of the general features of this great project. This plan will serve as a guide in the design of the future transmission line projects of this power system.

Another illustration of a fundamental plan is the nationwide toll dialing plan adopted recently by the Bell Telephone Companies. Toll dialing is the method of operation by which a toll call is completed by mechanical means directly to the called telephone in the distant city without the assistance of operators at the distant city or at intermediate points. The electrical impulses which control the switches at remote switching points may be originated by an operator at the originating point, or directly by the customer by twirling his dial.

Toll dialing has long been used in various parts of the country on a regional basis. A number of years ago we initiated studies to determine whether the results achieved by the operation of these regional networks and the possibilities of further technical developments made it desirable to plan for the indefinite extension of these forms of operation in one nation-wide interconnected network. Such a decision was made and a plan developed which affects all future development of toll telephone installations throughout the country.

The plan involved the adoption of a new principle, namely, that the digits transmitted into the machine for completing a toll call would designate only the destination of the call and not the route to be followed in reaching it—the route to be determined by the machine.

This made necessary the development of automatic switching machinery with greater powers of selection and direction of routing than had been produced heretofore.

The extension of customer dialing depends upon further technical developments. New forms of machinery are necessary to record automatically all the information required for billing the calls.

The plan involves major revisions of the general toll switching plan previously used by the Bell Telephone Companies. The new toll switching plan concentrates the new and complicated forms of equipment at a relatively small number of carefully selected points.

The plan involves development of radically new trunking plans, taking advantage of the ability of the machine to test rapidly a number of alternative routes if the route first selected has all circuits busy.

The plan involves the development of a non-conflicting system of telephone numbers covering the entire area of the United States and Canada. Any telephone in this area will be uniquely designated for toll dialing purposes by ten digits. These must be related closely to the local telephone number. The problem of meeting these two requirements without conflicts is one of great complexity.

I wish I could convey to you in a few words the fascination of work on this important and far-reaching plan. It will provide gradually for a marked and general improvement of long distance telephone service throughout the country. It will be a basic guide in the investment of hundreds of millions of dollars in the construction of toll plant. It establishes requirements for telephone equipment which direct years of development work in this field. It constitutes a major creative effort on the part of a large number of engineers throughout the country who have taken part in the vast amount of work involved.

While I have mentioned only two fundamental plans, engineering work abounds with other illustrations. Probably too there are many situations where a fundamental plan is needed and not made because of the preoccupation or limited horizon of those who would be responsible for such work.

A fourth type of engineering plan which should be mentioned can be described as a program. The project plan does not of itself inherently include any schedule of the times at which various parts of the plan will be carried out. Such a program, however, carefully coordinated, is necessary for the execution of the project. A fundamental plan is usually too forward-looking to be covered by a single program, but programs are prepared from time to time covering expected activity for a few years ahead. These programs are important to coordinate various projects for satisfactory development along the lines of the fundamental plan. The preparation of programs, therefore, while often associated with a project plan or a fundamental plan, is an independent act of planning.

Within my experience, engineering graduates are often aware in a general way of project plans and familiar with plans described in current literature. They are usually quite unaware of the scope and variety of the work involved and of the problems of coordination and evaluation necessary in arriving at the decisions which must be made in such planning work. They are likely to have no conception whatever of the fundamental plan. They do not have an appreciation of the importance of this type of planning in engineering work.

The Principles of Engineering Planning

I do not suggest that the student might be trained in his undergraduate work to be competent in engineering planning. Engineering planning is an advanced subject—one of the highest forms of engineering activity. Accomplishment in this field depends upon a creative imagination born of the union of natural ability and experience. All that we need to consider here is whether anything more

can be done than is now being done in the crowded years of the curriculum to train the young engineer in the techniques and principles which he will later apply in planning work and to give him an appreciation of the scope, amount and importance of this type of work in his future professional life.

There are certain techniques which are important in engineering planning, on which it seems to me more emphasis could advantageously be placed. Of first importance among these techniques I place those of engineering economy. This subject enters in an important way in all engineering planning as well as in other engineering work. I don't think that the young engineer is fully trained for professional work unless he is thoroughly familiar with the principles of engineering economy.

Another technique which applies to engineering planning work is that relating to precision. The inexperienced engineer working on an engineering plan may spend vast amounts of time and effort in working out degrees of detail which are not significant. In such a plan the engineer is dealing with the future with all of the uncertainties which that term represents. He must determine what are the most significant variables in his problem, what are the probable degrees of variation and what effect these have on the outcome of his study. I would say that because of considerations of precision a forward-looking study generally should include only those details which it is necessary or important to determine upon at the time. All other details should be left for further development by explicit plans made at the time action is taken on each part of the over-all plan.

The ability of the young engineer to apply to a planning project the principles of precision as above outlined certainly is helped by his knowing the principles of elementary statistics particularly of sampling and of the precision of results.

Engineering planning involves the use, consciously or unconsciously, of the principles of logic. The planning work should be inclusive—no alternative completely overlooked. There are historic cases where tremendous amounts of engineering effort were done unnecessarily because the work was started along the wrong lines. In practice, to be able to consider all alternatives requires ability in classification and comparison, so that the less favorable possibilities can be rejected by classes or groups rather than individually.

Througout the planning work it is necessary accurately to present and to judge comparisons of alternatives. These comparisons often involve quite dissimilar conditions and the inclusion of both tangible and intangible factors. To sum these up so that the correct decisions can be made at each point as the work proceeds is an important part of the technique of engineering planning.

Planning in Relation to the Curriculum

In approaching the question of what relation the subject of engineering planning has and should have to the curriculum of the engineering school, I have discussed the matter with 26 of the more recent engineering graduates in my own department. These men come from 20 engineering schools all over the country.

The men were unanimous in the opinion that it is important for the graduate to have an appreciation of engineering planning and nearly unanimous in believing that an effort should be made to get more of this training into the curriculum. Most of them recalled elements in their courses which they now recognize as training in planning, but consider that more could well be done.

As regards specific techniques which might be made a part of the curriculum, the most concrete item I have to suggest is engineering economy. Here is a considerable body of technical principles which are teachable. I have already expressed my opinion that these principles should be included in every

engineering course. The same thing can be said regarding the techniques which relate to determining the precision of results, the size of samples and similar elementary statistical methods.

In addition there is a considerable body of principle which relates to planning work. Some of this I have briefly suggested in this discussion. It might be called "Applications of Logic." While this theoretically might be the subject of a course, I am not suggesting that it be added to the curriculum. I have not seen any text which develops these principles in the tangible form necessary to make them attractive for use in engineering school courses.

Without adding any subjects to the curriculum, however, it would appear that there is great advantage in including planning problems and a discussion of planning methods in the present subjects of the curriculum to the extent this is practicable. This type of work is an excellent method of teaching the student to think, the basic aim of education.

An important opportunity to include planning work in the curriculum is presented by the laboratory exercise where the student is required to plan his own experiment in detail before going into the laboratory rather than being given instructions which he is to follow. I am strongly of the opinion that one laboratory experiment which the student has been required to plan completely himself is of greater value to him than two experiments in which he follows instructions.

In a few cases the young graduates whom I consulted referred to projects of a planning nature carried out by a group of students. In one case an entire summer course was devoted to this type of group planning. In several cases projects of a smaller nature planned by individuals or small groups were included in the regular winter work.

The more complicated forms of planning to which I have referred are necessarily beyond the scope of the student activities. There would appear to be advantage in giving the student as much appreciation of this work as possible. It would seem that seminars and lectures by men engaged in engineering practice could be so directed that they would bring to the student a great deal of appreciation of planning processes. To do this, however, would undoubtedly require a careful steering by the faculty of the subject matter and form of presentation. It might require that the presentation by the outside engineer be supplemented by discussions of the project by a professor who is skilled in analyzing the elements of the planning process.

Conclusion

The analysis which I have tried to bring to you can be summed up in four points:

1. The processes of engineering planning, particularly, of what I have called project planning and fundamental planning, are of wide and increasing importance in engineering work. It is advantageous to the young engineer to have an appreciation of the importance and scope of such work and to have as much training in the techniques which he will use in planning work as is practicable within the limits of the college years.

2. Certain techniques are important in engineering planning and other engineering work and should be a general part of the curriculum of the engineering school. Outstanding among these is engineering economy.

3. Teaching the student to think clearly and logically is the best preparation for work in engineering planning as well as other engineering work. The inclusion in the curriculum of simple planning problems would appear to be excellent training in this direction.

4. It should be possible to give the student an increased appreciation of what is involved in practical engineering planning work by directing to this subject seminars and outside lectures. Such direction would increase their value to the student.

Research and Development: The Nation's Balance Sheet in June 1951*

By ERIC A. WALKER

Dean of Engineering, Pennsylvania State College; formerly Executive Secretary, Research and Development Board

The Pentagon, designed to accommodate 18,000 people, is now straining at the seams with 32,000. Whether this is good or bad it is a small example of the pressure the national defense effort is exerting everywhere—not only upon our manpower and material resources but on the ability of the people to pay for it. We in the Defense Department are fully aware of this. We feel a keen sense of responsibility in our expenditure of the funds and manpower necessary to keep our defensive capabilities at a safe level. The magnitude of our task is illustrated by the fact that *military* research and development in 1951 costs more than seven times the amount of money expended on our entire *national* research and development effort in 1940. In my remarks concerning the nation's research and development balance sheet—and I am using the term "balance sheet" in its broad sense—I shall tell you something of the amounts of money we are spending and how they are being used, the factors contributing to the increased costs of research and development, the current technical and scientific personnel shortage and measures for relieving this, and the position and problems of the Research and Development Board. As a point of departure, I shall first compare research and development expenditures, both national and military, during the 1940–1950 period.

In 1940 the total *national* expenditure was about $350,000,000, while that of the *military* was in the neighborhood of $22,000,000. In other words, the military expenditure amounted to one fifteenth of the total national research effort. As of 1945, the national expenditure had increased to 1.1 billion dollars and the military expenditure—including that of the Office of Scientific Research and Development—had increased to $600,000,000. This military research figure was about one-half of the national total. During the five years preceding the outbreak of hostilities in Korea the military research and development budget, exclusive of atomic energy, remained more or less constant with an annual expenditure of around $500,000,000; but the increased international unrest after June 1950 was instrumental in more than doubling this. One estimate places the current national research and development expenditure at 1.75 billion dollars and another sees it as a total of 2.3 billion. Our military research and development effort now absorbs 1.1 billion dollars, with a further increase of about $200,000,000 expected in 1952. The 1.1 billion is apportioned roughly: $3,000,000 for work done in government laboratories, $650,000,000 for project contracts with industrial installations, and $100,000,000 for research conducted by colleges and universities. It is difficult to achieve any adequate measure of

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the expenditures *associated* with research and development, for the development eventually becomes testing and this is not paid for out of research and development funds.

Consider for a moment the effects of the budget increases. For one thing, we can expect that a large portion will be absorbed by rising costs. The Secretary of Defense recently stated that inflation has, in the past year alone, effectively taken from the military establishment about 7 billion dollars of the 35 billion voted to it by Congress. This inflationary trend has also been felt in the sphere of research and development.

A number of factors have contributed to the increased cost of research and development. As of December 1950, materials and service costs have gone up 19 per cent from the 1947 level and these are still rising. The salaries of employees under federal civil service increased about 13 per cent during the same period, and it is reasonable to suppose that there has been a comparable rise in those paid by industry and academic institutions. At present, the yearly cost of maintaining a scientist or engineer in a laboratory varies considerably even within the government. Approximations of such costs are: $26,000 for the Department of Defense and other government agencies (except the Atomic Energy Commission, where this expenditure runs to $30,000), $23,000 for industry, and $8000 for universities. These differences are a result in part of different definitions of a "scientist or engineer," but they also reflect variations in the cost of the equipment used and the amount of service help supplied the scientist by his organization. These constitute sizable increases over such costs even six months ago. Then there is the matter of overtime pay, necessitated by the current world situation, which will probably account for an additional 10 per cent increase in the cost of the research program. As a general thing, the type of research we are conducting requires very expensive equipment and facilities, such as large wind tunnels, high-speed electronic computers, and guided missile test ranges. Since most of these have no industrial application it is necessary that they be constructed and operated at government expense.

Engineering Manpower

I turn now to the problem of manpower, which I realize is a question of particular interest to this audience. One of our major difficulties at present is the acute shortage of engineers and scientists, particularly those trained for research work. The nation's scientific and technical manpower resources now total some 575,000 persons, of whom an estimated 25 per cent are equipped to do research. The 25 per cent figure represents roughly 130,000 research people, of whom about 25,000 are employed full time by the government, 70,000 by industry, and 35,000 by colleges and universities. The total number of engineers and scientists now required for the Department of Defense research program of 1.1 billion rounds out to 56,000, or 43 per cent of the total national supply. It is expected that in 1952 this percentage will rise to 52, with a total requirement for 68,000 technically trained personnel. If the research-personnel requirements of the Atomic Energy Commission and other agencies engaged in defense research are included, the requirement reaches a staggering 65 per cent.

The breadth of this military research effort is sobering as well as startling. We are confronted with the fact that a tremendous proportion of our scientific resources are being utilized for research on weapons, counter-measures, and techniques of warfare, and this must of necessity have a profound effect on our way of life. If we are to maintain a military research and development program and also provide for increased civilian research needs we must be sure that we are using our manpower as efficiently as possible. There have already been dis-

ruptions and dislocations in the fields of teaching and of academic and industrial research. In addition, we run the risk of lowering our national standard of living, of which we are justifiably proud, through the diversion of our scientific research and development effort from civilian consumer goods to materials with which to meet military requirements. This could affect the morale of our people adversely, with consequent impairment of our military machine. We must also beware of a condition in which basic research, the life blood of scientific progress, becomes excessively subordinated to applied research. Here, of course, it is encouraging to note that the picture has been brightened considerably by the formulation of a policy for military support of such research—namely that the Departments should budget no less than 6 per cent of their total annual research and development funds for basic research—and by the recent establishment of the National Science Foundation.

I should not like to give you the impression, however, that all of the money and manpower expended upon military research leads only to destruction of life, health, and property with the attendant human misery. Such research, however deadly its intent, almost always produces something with a constructive application. Chemical and biological warfare, potentially deadly weapons, have made important contributions to the medical and veterinary sciences. Studies of the action of nitrogen mustards, developed as toxic chemical warfare agents, have revealed the destructive effect of these mustards on white blood corpuscles. This finding suggests their use in treatment of leukemia and has led to such employment. Experiments with rinderpest, one of the most fatal animal diseases, have produced significant advances in the development of an effective vaccine against this disease.

Many manufacturing techniques used in the production of television tubes have resulted from research on cathode ray tubes used in radar. Military experimentation was responsible for a more ruggedized picture tube capable of maximum production in terms of quality and quantity. The technique used in sending television images from one station to another by radio links owes much to the microwave relay links and equipments developed for the armed services during the last war.

The airborne magnetometer, developed to aid in the detection of submarines, has proved a very efficient tool for geophysical prospecting for valuable minerals and for the determining of geological structures.

These few examples should serve to remind you that while we in military research and development are sowing dragon's teeth we are also sowing good seeds which are already yielding a harvest.

The great problem which confronts us at present is how to meet greatly increased demands without making wholesale inroads into the scientific staffs and faculties of our industries and schools. It is universally agreed that to make such inroads would be to court disaster. But where are the additional people we need going to come from? This is a question to which some of you gentlemen may have an answer. It is certainly one that we all must think about very seriously.

Declining Enrollments

Another critical aspect of the overall problem is the fact that while our military research and development requirements have been increasing at such a rapid pace, the number of college graduates in the scientific and engineering fields has decreased almost comparably. The fall-off in engineering college enrollments is particularly serious. According to the most recent figures I have seen, our colleges produced some 50,000 engineering graduates in 1950. This year will see a decrease to 38,000, and by 1954 the total is expected to be 18,000. Dr. James R. Killian has recently estimated the

number of 1954 engineering graduates to be as low as 12,000. Either of these figures would leave us considerably short of filling even the normal peacetime replacement need, and our demands have, of course, been greatly increased during the past year or so. I am reasonably sure that this shortage is also characteristic of scientific and technical fields other than engineering; and it cannot be alleviated in any short period of time. The situation will probably be even more acute 10 or 12 years from now, since an over-all decrease of 10 per cent in the number of high school graduates is expected between 1950 and 1958.

The explanation for this appalling shortage of scientific and engineering college graduates is not simple. The situation is no doubt partially attributable to the decreasing numbers of capable science teachers in our high schools, for it is these people who either stimulate or fail to encourage the desire for higher education in the scientific fields. A shortsighted view held by some engineering college administrators and faculty members a few years back may also be blamed in part. There was, as you all must remember, a widespread tendency to discourage prospective enrollees on the grounds that the employment market for engineers was in danger of being glutted! This view was probably based on figures contained in a report entitled *Employment Outlook for Engineers,* released by the Bureau of Labor Statistics of the Department of Labor. Although the completed report was not released until the late spring of 1949, much of the material was available previously.

Another complicating factor at the present time is the extension of selective service. A recent policy change has been effected whereby college students, through maintaining exceptional grades or passing a written examination prepared by Selective Service, may be deferred pending completion of their education, but it is too soon to determine how effective this will be. An unidentified student, commenting on the draft-deferment test, remarked that the Army is going to get a bunch of art students and psychologists if the test is used. If this young man is right we who are concerned with research and development will rest more easily, but I don't think it would be wise to count on it.

In addition to the demands of selective service, departmental call-ups of scientific reserve officers, particularly electronics specialists, are cutting into civilian scientific activities.

The ultilization of scientific and technical personnel within the Department of Defense is yet another aspect of the problem. The Office of the Assistant Secretary of Defense for Manpower is working on a policy for the most effective assignment of scientists and other specialists to military jobs. If adopted, this policy will help to prevent waste of scientific manpower acquired by the services.

There are certainly no ready solutions to the technical-manpower problem. The stepped-up defense program requires additional personnel, and it is clear that to a great extent these can be obtained only at the expense of other research and development activities. If there is unreasonable competition between various agencie for needed personnel, additional fuel will be piled on the fires of inflation and our research and development dollar will buy less and less.

Since I don't want to sound like the definition of a pessimist that I heard recently—a person who must appear unhappy in order to be happy—I should tell you that there are some promising aspects to the situation. As I said before, only about 20 per cent of our trained engineers and scientists are actively engaged in research and development, but ways are being explored whereby the use of the national reservoir of technical personnel can be maximized.

Engineering Manpower and Military Service

The Buckley Committee, a staff agency under the chairmanship of Dr. Oliver E.

Buckley, Chairman of the Board of Bell Telephone Laboratories, has recently been organized to advise Defense Mobilization Director Charles E. Wilson regarding coordination of government and private scientific research and planning for defense. One of the problems which it will consider is the availability of scientific manpower. The membership of this group includes William Webster, Chairman of the Research and Development Board; Dr. J. Robert Oppenheimer, Director of the Institute for Advanced Study, Princeton University; Dr. Hugh L. Dryden, Director of Aeronautical Research, National Advisory Committee for Aeronautics; Dr. Detlev W. Bronk, President of Johns Hopkins University; Dr. Alan T. Waterman, Director of the National Science Foundation; Dr. James B. Conant, President of Harvard University; Dr. Lee DuBridge, President of California Institute of Technology; Dr. James R. Killian, President of MIT; Dr. Robert F. Loeb, of Columbia University's college of physicians and surgeons; Dr. Charles A. Thomas, Executive Vice President of the Monsanto Chemical Company.

Problems dealing with the scientific-manpower shortage give rise to the question of some sort of national scientific service, however, and this is part of the over-all manpower problem, which certainly cannot be solved overnight. In line with this, the American Association for the Advancement of Science recently approved a resolution stating in part

> . . . a system of Universal *National* Service, as distinct from Universal *Military* Service, should be instituted, to be administered by a carefully qualified civilian agency that will grant no deferments but will allocate all scientific and technical personnel to such national service as their individual training and skills permit, and national needs require.

It should be added that a number of academic institutions are also offering assistance in the solution of the manpower problem. To meet the nation's needs for a greater number of broadly trained engineers, several schools of engineering have recently entered into agreements with liberal arts colleges to offer students a combined five-year program leading to both a B.A. and B.S. degree. Under the program, students spend three years in the colloge of their choice, taking a liberal arts course. Upon recommendation of the liberal arts school, they will then be accepted by the engineering schools for two years of specialized engineering training. At the completion of the entire program they will receive two degrees.

Another partial solution that is receiving consideration is the full utilization of the scientific resources of our allies. I believe that something of this sort is being done through the London Office of the Office of Naval Research and through certain State Department scientific-liaison agencies. It may soon be formalized by agreements between the NATO countries. There is already a considerable exchange of scientific information between the United States, the United Kingdom, and Canada and it may also be possible to make use of the expanded research effort in certain Latin-American countries which is now receiving support under the Point IV program.

Military Research Program

After this statement on the over-all budget and manpower situation, and the attendant problems, you are probably wondering about the organization of the military research and development program. One of the questions we are often asked is, "Is there going to be another organization of the OSRD type?" I cannot say positively that there will be no such organization, but I can tell you that none is contemplated at present. The research programs of the services are more complete than they were at the time when the OSRD was in operation; also, more scientists are actively employed in the program and more advice is sought from outside scientists. Thus the combined

research and development program encompasses the types of activities carried on by OSRD. The services now administer their own research and development, which is carried out in government laboratories or by contract with industrial organizations or universities. The programs are guided and constantly reviewed by the Research and Development Board.

Before I tell you what the RDB is and how it functions, perhaps I should tell you what it is *not*. It is not an operating agency; and by that I mean that it does not let contracts or administer research and development programs. It serves, rather, in an advisory capacity; the details of carrying the programs out are left to the military departments. This division of responsibility is carefully delineated in our directive, which states: "The Board shall not direct or control the internal administration of the research and development activities and programs of the several departments and agencies of the Department of Defense." In addition to program guidance, our specific duties include the review of departmental budget estimates, review of facilities proposals, advising the Secretary of Defense on obligation of funds, preparation of estimates of the technical capability of weapons and countermeasures for consideration by the Joint Chiefs of Staff, and elimination of undesirable duplication.

Besides the seven-man Board, composed of a civilian chairman and two members from each of the military departments, there are a number of committees which correlate work done in their respective fields and advise the Board and the Departments accordingly. These Committees, of which there are 14 at present, cover such subjects as atomic energy, chemical and biological warfare, and guided missiles. They are assisted by full-time secretariats, and by panels, subpanels, and working groups. Since the committees and their subgroups are composed of experts from industry, universities, and the military departments and other government agencies, they assist also in bringing about a fruitful cross-exchange of information. The largest committees at present are Aeronautics, Electronics, Guided Missiles, and Ordnance.

We believe that we have contributed a great deal to the integration of the various military research and development programs and to the over-all program as well. We are faced, however, with a number of basic problems which make our task more difficult and, I fear, prevent the research and development program from attaining the effectiveness which we would like to see.

One of the Board's most urgent problems is the need to find a qualitative measure of the research and development program. The popular tendency, which I think is a fallacious one, is to measure the quality of research in terms of expenditures and numbers of people employed. This carries over into civilian scientific endeavors as well. For example, there seems to be a feeling that if 100 million dollars are spent on cancer research, the return will be 100 times what would have been achieved had only one million been spent. Any scientist knows, however, that this is not necessarily true. The ratio between heavy expenditures and probable success in solving the problem is a favorable one generally, but it is not infallible. Such things as expenditures and numbers of personnel cannot, therefore, be accepted as measures of accomplishment. They merely indicate the use to which the nation's financial and manpower resources are being put.

At present the Research and Development Board has cognizance over approximately 8500 research projects which range all the way from improved shipping containers to a guided missile with a 5000-mile range. It is, of course, necessary to concentrate on development of some of these projects at the expense of others; so we must continually ask our-

selves and others the questions: How important is the problem? How valuable is the result of our effort in this direction going to be? The answers to these can't be arrived at simply; we run into a great deal of conflicting opinion which makes difficult the assessment of relative importance and probable return.

Evaluation Methods

In industry one can approach the probable return by estimating the net profits which might be expected to accrue from a product under development. In war, however, success is not measured by so simple a yardstick. It is measured, rather, by numbers of enemy dead or incapacitated, by numbers of our people *not* dead or injured, or by territorial gains, and our weapons are developed in accordance with what we think these would be. On the other hand, just to complicate matters still further, the most valuable weapon which could be developed would be one which would deter prospective enemies from aggression, rather than decimate their armies or civilian populations. Military history for centuries demonstrated that for every offense a defense could be developed, but the possibilities inherent in such weapons as the super atomic bombs are so frightful that the possession of sizable numbers of them by any nation would give would-be aggressors grounds for serious consideration.

To take a hypothetical example, suppose that a cosmic ray capable of destroying all life within a radius of 100 miles could be developed. How would you measure the value of this in dollars and cents? Could you say that the research on it would be worth 100 million dollars—or one million? So you see that first of all we need a set of measurements for determining the value of projects.

The first thing that needs to be done in evolving such a set of measurements is to determine the relative importance of the various types of operations. Are land operations more important than strategic bombing? Are amphibious operations of more value than biological warfare? What is the relative importance of guided missiles and electronic communications systems? In these large areas the answers are subject to endless debate. One can estimate the relative effectiveness of modes of warfare only by approaching them in terms of specific weapons systems and individual weapons.

The second need is for a method of evaluating the probable success of a given research project. The most revolutionary idea is of no use if it can be proved impossible to develop and apply, or if its development and application would be too costly in terms of dollars and man hours. But again, the difficulties of accurate assessment intrude. It is obvious, however, that once we can determine the importance of a problem and the probability of solving it we shall have two important criteria for our measurement of a research and development program.

A third point which requires consideration is the efficiency with which a research program is being conducted, on both the administrative and working level. No two teams of researchers are equal in talent; nor do the teams have the same backgrounds, facilities, and supporting staffs. If we could obtain some workable measure of efficiency of research groups we could weed out the inefficient ones and foster the qualities which make others successful. Individual laboratory directors can often find a relative standard for judging the productivity of their workers, but officials who coordinate the work of people in widely separated laboratories where they have slight acquaintance, if any, with the workers have quite a difficult time. This difficulty is magnified when a research coordinator or contract administrator is trying to decide whether a certain project should be put into the hands of a government laboratory, an industrial organization, or an university.

Administrative Problems of Government

One of the great problems that besets government research administrators lies in the fact that, without personal standards for measuring the difficulty of problems or the efficiency of their research teams, they must make administrative and scientific decisions involving the expenditure of millions of dollars. Also the current personnel shortages sometimes necessitate the use, as administrators, of persons with little experience in such lines. Here the government deviates sharply from industrial practices, since most industries go to great lengths to procure the services of outstanding administrators, who are paid several times the amount their counterparts in government receive for administering many times the same volume of research. The net result of this is that government research, even when carried on by industrial installations, is often done with much lower returns than that conducted by industry directly.

Another problem confronting those who guide government research is the question of when to consider a project finished and stop work on it. A research director plans a program for solving a given problem and estimates the time and money which will be required. At the end of that time the problem may not be solved, usually because of difficulties which cannot be identified. There may have been unforeseen technical obstacles or the assigned staff may have been incompetent. At any rate, the question arises: What should be done? Should the project be continued or cancelled? How imminent is the solution? Those doing the work nearly always want the program continued, and this feeling is apt to carry over to the research director. The end result is that sometimes programs which ought to have been cancelled long ago drag along, absorbing money and manpower that could be used to much greater advantage somewhere else.

A problem equally important and equally difficult is the question of when the research phase should be terminated and the device put into production. Rarely is a research man satisfied with the results of his work. He can always see how the device can be improved, made more efficient and more reliable, and at times (one feels) more complicated. Many difficulties arise in deciding whether the original problem has been solved to the extent where a production line can be set up. The OSRD encountered this problem in World War II and solved it in a reasonably satisfactory way by establishing the Engineering and Transition Office. This Office was staffed by people who understood military requirements and, where these existed, the specifications for the completed device. They also understood the working of the prototypes constructed by the researchers. Lastly they had some comprehension of manufacturing processes and materials; so, from this collection of information, they were able to decide when the item should be put into production. The military services now have evaluation groups to which the making of such decisions is entrusted.

In closing I should tell you that the over-all military research and development picture is quite a promising one; although, as I have indicated, there are some spots which need touching up. It was inevitable that in the sudden huge expansion of the program certain problems should arise; but these problems are widely recognized by the military departments and other government agencies, and all possible steps toward their solution are being taken. We have been successful in developing greatly improved weapons. Two additional positive results are the new sense of awareness of the importance of technology to modern warfare and a mutual respect between the military and the scientists.

Engineering Manpower for Industry*

By DON G. MITCHELL

President, Sylvania Electric Products Inc., New York, N. Y.

It would be presumptuous of me to offer you any statistics on the engineering manpower situation. I am sure you must know by heart how many engineers were graduated last year and this year, and how many are in each of the classes now in college. You know how representatives of industry have swarmed on your campuses desperately trying to sign up some engineers at attractive starting rates.

It would be my guess that this year not one of you has had the spectre of unemployed seniors to plague you. Every graduate either has been placed or can be placed, once he makes up his mind which bid he will accept. Aside from the fact that some of these young men will not return from their tour of duty with the Armed Forces, it must be a comfortable feeling for you to know that as you start on the finishing of next year's model none of the last is left over in stock.

It is not as comfortable for industry. As you well know, there are not enough engineers to go around.

Defense Requires Engineers

We are trying to maintain a civilian economy at the same time that national defense requirements are increasing and use of critical materials is being restricted. This is a problem that needs engineers and more engineers, but the defense services also need engineers.

This isn't anything new. We have had national emergencies before. When shortages developed we either learned how to get along with what we had or we turned to some substitute source. Sometimes the necessity has brought practices that have been beneficial long after the emergency has passed. Such a situation could develop in the employment of engineering manpower.

Perhaps we can draw some comparisons between engineering and some of the skilled trades. At one time a machinist had to spend six or seven years learning his trade. When he became a journeyman he could make up the work and operate any machine tool. Mass production industry, however, couldn't wait as long as that to train machine mechanics. Men were trained for special work in a fraction of the time it took for the overall training.

Welding is another skilled trade that takes a lot of training to learn all the tricks of the trade. During the last war women were trained for special work in a matter of weeks.

Training Wasted

It seems to me that we have been giving thousands and thousands of young men a four year training in the fundamentals of engineering, at considerable expense to them, and then putting a great many of them in jobs that could be done as well by people with a fraction of the training.

For a long time, engineers were poorly paid by comparison with college trained men in other professions. Supply and demand had, of course, more than a little to do with it, but an important factor

* Read at Annual Convention, American Society for Engineering Education, East Lansing, Mich., June 28, 1951.

was the type of work they were doing. Even so, I am none too sure that industry did not pay more to engineers for doing that kind of work than it would have had to pay to non-college trained people.

How many engineers are hunched up over a drafting board on mechanical work? How many are compiling statistics and drawing graphs? How many are playing nurse to ailing machines? How many are making routine tests? How many are caught in blind alleys doing specialized work that requires no particular talent?

In other words, do we have a shortage of engineers or does it just look that way because of the manner in which we have put engineers to work?

Would we have a shortage of engineers if we replaced them with people trained to do some of these routine jobs on which engineers are now being used?

Obviously, I am speaking generally because, of course, there are many men who succeed in getting an engineering degree who will never be able to go beyond routine work. People so mentally limited would probably enjoy life more if they never had gone to college.

If what I am suggesting could happen, actually does come to pass, I believe that industry, engineers and education will all benefit.

Reevaluation of Formal Training

Let me ask you, who do the original selecting and the basic training, if it is fair to leave the responsibility for ultimate determination of an engineer's employment entirely to industry? That, I know, is an academic question and we could argue it all night long and get nowhere. Nevertheless, I think you will agree that industry has a point when it says that every time it is saddled with a frustrated individual it acquires a possible point of social infection.

Probably the greatest gain would come through a reevaluation of the formal training of engineers in the light of what industry really wanted. This is a subject which has been discussed so much that there should be little left to say. Nevertheless, I am sure that if industry finds it can fill advantageously the routine jobs with people who are not engineering graduates, our engineering schools and industry will find it necessary to reappraise the quality of the formal training.

Just why do we need engineers in industry? One could answer by enumerating the different kinds of jobs in which engineers are employed, which is what industry does in its recruiting college work. If what I have been saying, however, has any validity this approach would offer us no constructive solution to the problem of engineering manpower adequacy. Instead, I am going to discuss the larger aspect of our need.

Sound National Defense Needed

Of first importance today is the creation of a sound national defense that will protect us and the other free nations of the world from the spread of aggression by Communist countries. Without the United States the rest of the world is doomed. Europe is too weak from the last war to resist. Asia has no defenses worth mentioning, nor has South America.

What do we have that makes us so sure of ourselves? It isn't our natural resources of metals, fuels, forest, soil and water, for the opposition has these in abundance and, as we deplete our own reserves, we find ourselves more and more dependent on others.

Nor is it our population of one hundred and fifty million people. The nations within the Russian orbit greatly outnumber in population the peoples of the free nations.

We Excel in Productivity

Our physical superiority lies in our creative and productive abilities—broadly in the field of engineering.

The United States has two things which have defied competition from the

rest of the world—two things which we call by different names but which are as inseparable as Siamese twins. I refer to our worker productivity and to our standard of living. Without a high productivity there could be no high standard of living and without the latter there would be no reason or excuse for the former.

However, this can be no hare and tortoise race. Once you are out in front you must stay in the lead. With the manpower and the resources that the Russian controlled countries have, any time they get in front they win the race. Not only must we stay in front but by the same relative margin, in order to make up for any superiority in numbers and natural resources they have.

Russia Respects U. S. Production

Russia has a great respect for this margin. For some time she has been testing it anew to find out the actual superiority of productivity over sheer numbers. At one time this year the reported losses in Korea gave the ratio as 100 to 1. Perhaps Russia will try out other combinations to learn whether or not there is a ratio that will warrant an all out war on her part. What that is, of course, I do not know but I am confident that today we have the superiority that will win if a showdown becomes necessary. Our problem from here on is to keep that winning superiority and enough besides to remove the threat of war.

Productivity is the job of getting more with what you have. It means better methods, better machines, substitute materials to take the place of those in short supply, reduction of waste and the application of scientific discovery. And while we are finding out how to make better use of what we have, we are making more of it available for the expenditure of an hour of labor.

Productivity is the foundation on which our national defense rests. It is the basis for our American standard of living. It is the only way in which inflation can be kept in check. The engineer is the man to whom we must look for the techniques, the methods, the know-how.

Engineering Needs Broad Thinkers

That is a big job and it is getting bigger all the time. For that reason men are needed who have a breadth of concept and who can think and think big.

Engineering basically is the application of scientific knowledge. Engineering, however, because it lives in the realm of practicality, does not and cannot have the exactness of science.

Engineering for industry of necessity is a compromise. For the most part our problems involve the weighing of a great many factors and conditions. If it were possible to have a single answer then our engineering problem would be simple because then we could design a computer to do all of our engineering work.

Seldom is there one and only one correct answer. As a rule there is a choice of directions to take and it is even possible at times to have solutions that appear to be almost 180 degrees apart. Because this is the case industry wants men who are broad enough in their thinking to see all the possibilities and sound enough in their judgment to give them their proper weight.

For years engineering school faculties have asked industry what it wanted in the educational program. It has been a sincere search and just as sincerely industry has said to train the boys in the fundamentals. Industry still says this, but I am not at all sure that industry has made it clear, or that our engineering schools have always understood what was meant by fundamentals.

Balanced Curriculums Offered

Too often, I am afraid, this has been taken to mean the mathematics and scientific principles of the particular brand of engineering. Such a narrow interpretation gives rigidity to instruction and restricts the student's thinking at a time when he should be expanding his outlook.

Of course, not all schools hold to the narrow interpretation. The more progressive ones have shown an understanding of the needs of men who will go into industry by offering them a balanced curriculum.

I have heard it said, as I am sure you you have, that there is a noticeable tendency among engineers to become introverts. As an example of this tendency, it is pointed out that engineers fraternize more with other engineers and are more shy with other members of the public. How much of this there is I do not know, but there is enough at least to have made it noticeable.

It would be difficult for me to believe that engineering attracted introverts, but I can understand how men who have not had a broad education, and who, by the very nature of their work, are not forced to have many public contacts, can have somewhat restricted social interests. This to me does not signify any inferiority complex as attaching to the profession but rather reliance for social contacts in a narrow area of compatibility.

Men in other professions such as law, medicine, and the ministry, are, by the very nature of their work, thrown constantly into close personal contact with lay people. Their interests have to be those of the people they work with and for. Engineers, on the other hand, are not so often required to sit down with lay people. That they fraternize more with birds of the same feather is understandable, particularly if their education was restricted to a narrow interpretation of fundamentals.

Stimulate Outside Interests

Industry would be much better served by engineers who have the interest to grow outside the boundaries of their profession. Stimulation of this interest, of course, can and does take place frequently after the men have left school and are on the job. It seems to me, though, that more could be gained by orientation in the early years of schooling. The idea is not new but, I am afraid, the practice is too often perfunctory, especially if the sessions are conducted by someone who knows the words but not the music.

Those of us who have had a diversified experience in industry can see a great many opportunities for engineers. How much better it would be if engineering students saw these in their early undergraduate years so they could make better choices in their electives. Can it be that the declining enrollment in engineering schools is a reflection of a growing public feeling that engineering offers less opportunity than other occupations?

Engineering Offers Many Opportunities

The nice thing about engineering is that it *does* have so many opportunities, more opportunities as a rule than there are experienced men to fill them. My company, for instance, is a large employer of engineers but we are constantly hard pressed to find enough management men for our expanding production facilities. This year we expect to start construction or put into operation new factories in nearly a dozen different places. Not only does our industrial relations department keep close watch on men of promise within the company but it refuses to permit men who are ready for larger responsibility to be held back by supervisors who are reluctant to give them up. Nevertheless, it is not easy to find the kind of men we want for the more important jobs.

The men we want most are those who have a deep respect for hard, honest work and an abiding faith in the justice of the rewards that come from such work. We need young men who have a mature outlook with respect to occupational integrity and a realization that they are no longer children who have a right to be cared for, but are now men who must be worthy of their hire. We want men capable of growing and becoming leaders. We want men who can adjust themselves to changing conditions without losing vision. We want men who are flexible

enough to accept new ideas, yet so rigid in their principles that they will not shirk responsibility or lose any of their incentive to reach their goals.

Important Fundamentals

Here are some fundamentals, it seems to me, that are just as important as the basic theory of electricity or an understanding of differential equations.

As you can see, we are looking for engineers who can grow and we expect to get them. By no means are we as discouraged as a friend of mine who, after discussing industry's needs all one afternoon, was asked by a college president what the colleges could do differently. His reply was, "well at least you can teach them to read and write."

Maybe that was a little harsh, but I can say "Amen" to the writing part and add speaking, as well. It does not do a man much good to have ideas if he cannot make somebody else understand what is in his mind. Until thought transference, or mental telepathy is perfected, I am afraid we must rely on the normal means of communication.

Engineering manpower for industry, as I have tried to show, is not a subject that can be discussed entirely quantitively. There is a quality angle as well.

Quality Deficiency

A quantity deficiency is no more serious than a shortage of some critical materials. Ways will be found to use what we have more effectively. Supply will be increased wherever possible and substitutes will be sought. A deficiency in supply of men qualified to grow into important positions is a much more serious matter and one that should concern us not only for the moment, but for the future. Surveys have been made of the number of men graduating from engineering schools each year and the number still to graduate. Do we know nearly as well how many engineers are needed?

What is normal? Are our schools geared for that figure or are they geared to carry a peak load? Is it, for financial reasons, a temptation to take in all the students that can be accommodated without thought for the employment opportunities for graduates?

When colleges take in too many for the demand, the pay drops and until fairly recently, engineers as a whole were not well paid. When the supply is more than adequate more men get pushed into blind corners where opportunity ceases to exist. Too many engineers make employers careless of their use.

Fewer Graduates

Right now, and for several years, the number of men graduating from engineering schools will be considerably less than before. In numbers they apparently will not be enough and something else must be done to make up the deficiency. The concern of industry will be whether the classes of the next few years will make up in quality what they will lack in quantity.

With fewer students the engineering schools should be able to give more attention to the individual and perhaps more time to counsel with him, and inspire him.

It is true that with very small classes almost anybody who graduates can get a job. It is equally true, however, that should such conditions last more than a year or two, as it appears they will, the need for especially well-trained men will be greater than ever.

Emergency caused manpower shortages, such as we have today, can be solved by emergency measures, whether it be mechanics or engineers. Shortages which spring from other causes should be studied to find out why they exist and measures taken to remove the causes.

Only let us be sure, before we start building back too far, we know how many are needed. Let us be sure we know what the men are being trained for and that the work cannot be done as well or better by someone who has not had a formal education.

In other words, let us know what we are doing from here on in, and why.

The Point 4 Program: A Challenge to Engineering *

By DR. HENRY G. BENNETT

Administrator, Technical Cooperation Administration, Department of State
President, Oklahoma A. & M. College

I am grateful for the opportunity to meet with the members of this society because you represent a field of endeavor which is of vital importance to progress in our nation and the rest of the free world. I am also grateful for the chance to visit with my friend and colleague, President Hannah, who as most of you know, is a member of President Truman's advisory board on the Point 4 program. Tonight I want to talk with you about the Point 4 program, which I have the honor to serve.

In seven months I have discovered some remarkable things about the Point 4 program. One is that almost everybody seems to like the idea of the program even if he doesn't know much about the details. Another is that practically everybody who gets to know about Point 4—wants to do something to make it a success.

I suspect this society is interested in the Point 4 program and that you are going to want to do something about helping it along. Otherwise you would not have invited me here this evening. At any rate, I am proceeding on that assumption. All you are going to hear from me tonight is talk about Point 4 and the role that engineering and engineering education can play in spreading its effectiveness.

Because of my work in the Point 4 program, I am particularly aware these days of the importance of engineering and engineering education in promoting the economic welfare of people everywhere. I say particularly aware because under ordinary circumstances I may go for days without giving engineering a thought. And that is in spite of the fact that as an old Oklahoma dirt farmer I have had occasion to brush against several fields of engineering—soil engineering, chemical engineering, agricultural engineering, food engineering, as well as the civil and mechanical fields most people think of as engineering. For the fact remains that many of us do not stop to think about engineers or engineering until we see a bridge being built to span a great river or a superhighway being cut through a mountain.

We in the Point 4 program are constantly being reminded of the vital role that engineering plays in modern life because of the sharp contrasts we see between life in America and life in the places where the Point 4 program functions, the so-called underdeveloped areas of the world.

Close to the People

We now have more than 400 technicians working in some 30 countries in Latin America, Africa, the Middle East and Asia on Point 4 projects. These technicians work with government officials who may be either popularly elected or hereditary monarchs and on a grass roots level with plain citizens in cities and on farms. The work of our technicians is mainly in cooperative efforts to teach people to raise food production, to wipe

* Presented at the Annual banquet of the ASEE, East Lansing, Michigan, June 28, 1951.

out disease and to improve and expand their educational systems. But Point 4 workers are engaged, also, in advising governments on how to modernize their administration and services, in advising on programs of general economic development involving the construction of power plants and irrigation systems, and in the establishment and efficient operation of new industries and the modernization of old ones.

These Point 4 technicians are engaged in demonstrating and teaching technical skills rather than in spending money for capital investment. They are not building public works with American taxpayers' money. Rather they are advising foreign governments on the proper way to build public works financed with local capital or loans from outside sources.

But regardless of the particular project a particular technician may be engaged in, he is likely to be dealing at least part of the time with problems involving engineering.

In the United States just about everything we see, touch or taste in our everyday life is the product of some kind of engineering skill. Pasteurized milk is an old example but concentrated milk is new. Rayon is relatively old but orlon and daeron are comparatively recent. Automobiles and airplanes are familiar means of transport but automatic transmissions and jet engines are new. Radio and motion pictures are taken for granted, but color television is only beginning. All these things, however, the old versions and the new, are the products of research on which engineering has been applied to bring them to multitudes of consumers at reasonable prices.

The contrast is astounding when we turn to the underdeveloped areas.

Toward Self-Sufficiency

For example, a few years ago Panama wanted to increase rice production. One of our technicians went down there—this was before technical cooperation became an official arm of U. S. foreign policy on a world-wide scale—and found that because the Panamanian farmer used ancient methods of cultivation he could not possibly take care of more than 2½ acres of rice a year. Our man showed the farmer how to use certain kinds of equipment and he was soon cultivating as much as 50 acres single-handed. Now Panama is self-sufficient in rice production and we have a new market for farm equipment.

Our people looked over the economic problems of Iraq. They found that the Tigris and Euphrates Rivers rage unchecked in flood season and fall to a comparative trickle in the dry season. The result is that 7,000,000 acres of land are useless for agriculture and that an area of equal size is not as productive as it should be. We are sending engineers to Iraq to advise on flood control and irrigation works construction.

I've been struck by some of the things I've seen myself. In Ethiopia I found topsoil 12 feet deep. That country could produce enough food to supply all the people of Europe. That is if its farming and farm processing were modernized and if it had roads and harbors so that its production could be taken to market —all engineering problems in greater or lesser degree.

In general I can say that engineering and engineering education have been lagging in underdeveloped countries. We find wonderful examples of scientific research which are useless because the engineering knowledge is lacking so that they can be widely and economically applied. Here a plant scientist has developed an excellent new strain of wheat: high-yielding, disease resistant, hardy in dry soil. But there is no way for the farmer to take advantage of it. It is as if Fleming discovered penicillin but people kept dying of disease because there was no engineering skill to produce the drug in large quantity and at low cost so that the majority of people could make use of it.

So the fact is that lack of engineering skill and knowledge is one of the reasons why the average income in underdeveloped areas is one-tenth or less of ours, why millions live between malnutrition and actual starvation, why two persons out of every three suffer from malaria or some other preventable disease.

The fact is that engineering is one of the supporting pillars of our own prosperity and that it is one of the absolute essentials for swift and sound economic progress in underdeveloped areas.

Great Need for Engineers

What we need now and are going to need more each year is a corps of engineers trained in all branches of the profession who can put their skills into practice in foreign lands, and more than that, who can teach their skills to the people of foreign lands. We need and will increasingly need people who are both engineers and educators. It is because this need exists that I am particularly happy to be talking to you tonight. I hope you will put this problem of increasing engineering knowledge and education in the underdeveloped areas of the world on your list of important things to be done.

The more we study the problems of underdeveloped areas the more we realize that the gap between their standards of life and ours is mainly a gap in engineering skills. The Point 4 program is designed to bridge that gap by making some of our knowledge and skill available to other people. And I am pleased to be able to tell you about some experiences which prove that this process is effective and that it is relatively low in cost.

For example, *Civil Engineering:* One of the major handicaps of the underdeveloped countries is lack of transportation and communications. Take Africa as an example—a continent more than 5400 miles from north to south and 4500 miles from east to west, with no through routes, either railroads or highways, for transporting people or merchandise. In fact, there are few miles of railroads or reliable highways on the whole continent. The same problem exists in many parts of Latin America and Asia. In some areas, the wheel is still unknown. Yet the building of roads is possibly the greatest single means of opening up new regions to development and quickening the economic life of a people.

Assist in Planning Roads

Under Point 4, we are sending engineers of the Bureau of Public Roads to countries that ask for technical help in solving their transportation problems. Often, their surveying and planning paves the way for private American engineering firms to build roads under contract. We hope that the services of private companies will be increasingly in demand as our Point 4 technicians point up the need of building roads and show how it can be done.

In Bolivia there is a great potential food producing region larger than Texas lying east of the high Andes. American agricultural technicians are working with the Bolivians to solve the technical problems of growing food, raising cattle and cutting timber under humid, tropical conditions. But probably the real key to the situation is transportation to get the food from the fertile lowlands to the food-deficient high plains of the Andes, where the majority of the Bolivian population is concentrated. A highway is now being built by American contractors to connect with a railroad leading to the capital. The Bolivian government is paying for this, partly with its own funds and partly with a loan from the Export-Import Bank.

Aeronautical Engineering: Many of these countries, although still needing railroads and highways for bulk transportation, have leaped into the air age while still depending mainly on the ox cart. In some countries, the airplane is the only means of cross-country travel. They need new, improved airports and

all the services that go with air transportation. Aeronautical engineering itself, with its constant improvement of plane design and performance, will continue to contribute to the economic development of these countries.

Nautical Engineering: Some underdeveloped areas possess extensive water highways—great river systems like the Amazon, which could accommodate far more shipping than is now using these waters. This situation, it seems to me, is a challenge to nautical engineering. There must be ways, yet undiscovered for designing craft for more economical and efficient operation in areas where waterways are the main arteries of travel and trade.

Harbors and Docks

Harbor development and dock facilities are also among the urgent needs of many countries that want to expand their foreign trade. When I was in Ecuador recently, the Government there requested the assistance of American engineers in developing plans for opening up the port of Guayaquil to ocean shiping, so that large ships could take on and discharge cargo there, instead of having to stop some distance down the river and use lighters, as at present. We promptly sent an experienced American engineer to look into the possibilities of that project.

Our records are filled with examples of amazing results achieved by American sanitary engineers working abroad. The water supply and sewage systems they have planned and supervised in communities in Brazil, Mexico, Chile and other countries have brought a dramatic drop in typhoid and dysentery. The draining of swamps, coupled with the application of insecticides and other measures, has brought an equally dramatic reduction in the incidence of malaria, the scourge of the tropics.

Geological and Mining Engineering: We all know that one of man's great sources of real wealth is the minerals brought out of the ground. Yet probably half the world has never had a thorough geological survey with modern methods. Most people consider Africa a poor continent, without stopping to think of the gold, diamonds and other treasures taken from African mines.

More Precious than Gold

Yet today precious metals and gems are not the most valuable materials we get from the earth. In the aggregate, the oil and coal extracted every year are worth far more than the gold and diamonds. One of the greatest needs of many countries is to find and use sources of economical fuel. The baser metals, including iron ore, are essential to economic development. Nor are metals and fuels all we need. I was told recently in Bolivia, where fortunes in gold, silver, tin and other minerals have been mined, that the government would like to have a geological survey in the hope of finding, among other things, phosphate and lime that would help the country produce enough food.

Under Point 4, we have geologists in twelve countries of Latin America, Africa and Asia helping to make inventories of mineral wealth and ground water supplies. In some instances, our mining engineers are helping work out more economical and efficient extraction methods. American geologists working with Brazilian geologists have scientifically confirmed the existence of rich magnanese deposits, with the result that American steel companies are going into partnership with Brazilian capital to develop these deposits. I am convinced that unknown treasures remain to be discovered and mined in Africa, Latin America and other parts of the world, and that our geological and mining engineers can help the people of those countries find and develop vast new sources of wealth.

Electrical Engineering: Many countries without coal or oil have another great source of energy—water power. Civilization really begins with the harnessing of heat energy for the work of man. Human slavery has been elimi-

nated largely because man has found other and far more efficient sources of energy—mechanical power that has enabled our own people in this country to multiply their own physical strength many times over. Our coal, oil and waterpower have made possible our amazing industrial development, and the same is true of Britain, Germany and other industrialized nations. And rural electrification has done more to increase our agricultural production than many of us realize.

The same thing can be done in the less developed countries. We know that Africa, for example, has some of the greatest unused water-power in the world —in the Nile, the Zambesi and other rivers. The same is true of many countries in Latin America. In the development and utilization of hydroelectric power, America can furnish much of the engineering knowledge to provide other countries with the mechanical energy that is essential for their progress.

Agricultural Engineering: Here is one of the most varied and most promising fields of all. Most of the underdeveloped countries are in the tropics, where the rain falls in torrents in some seasons and there is drought in other seasons. The hot sun rapidly leaches the nutrients out of the soil. When we clear and cultivate the land under these conditions, we have to protect it with dams, catchments, terracing, cover crops and other methods that are well-known. These measures are necessary to keep the top soil from washing away and the plant food from being lost.

Water is Pressing Need

The major limiting factor on food production and economic development in general in the semi-arid areas of North Africa and the Near East is lack of water. The people of that area need to store up the water in the rainy season and use it for irrigation in the dry season. The Romans largely solved that problem 2000 years ago. All through North Africa and the Middle East, we find the remnants of the dams, reservoirs and canals which in Roman times enabled that area to support much larger populations that can exist there today. We recently made a contract with the American engineering firm of Knappen, Tibbetts and Abbott to go into Jordan and show the people how to restore and expand these old Roman works so that they will have enough water. The same thing can be done in other countries of that area. It is not a costly process, because most of the work can be done by the people themselves, with local materials.

I want to explain that Point 4 is not in the business of building or financing large-scale projects in other countries. We help with the planning and technical direction, but the cost of construction must be borne by the other country with its own money, with help from private investors or with loans from international lending agencies. Many of these projects can be financed on a self-liquidating basis. At any rate, the cost need not fall on the American taxpayer.

For the last eight or nine years, American agricultural technicians, including engineers, have been cooperating with Peru in a joint service under the able leadership of Jack Neale of the Institute of Inter-American Affairs. I want to tell you about just one of the things that have been done.

Along the coast of Peru, as you know, is a strip of desert, caused by unusual climatic conditions. There is no vegetation except where the few rivers run from the mountains into the sea, and sometimes even these dry up. One such river is the Piura, in northern Peru. In normal years the farmers in the Piura valley grow the only crop of long-staple Pima cotton in Peru. It sells at a premium and ordinarily brings in about $8,000,000 a year. But for the last three years the river has practically dried up. The loss in the cotton crop is conservatively estimated at $15,000,000.

Find Way to Join Rivers

Nearby is another river that does not dry up. Agricultural engineers of the joint service made studies that showed that the waters of the constantly-flowing river could be diverted to the Piura. This would not only assure a cotton crop every year, but also add another 50,000 acres to the 75,000 now under cultivation. As a result of those studies, the Peruvian government is now considering contracting with an American engineering firm to construct a short tunnel to save the cotton farmers.

Even more important than bringing new land under cultivation, however, is the multitude of little things which, repeated by large numbers of farmers, are increasing production on the land already in use. These are simple things. In some cases, it means designing a suitable steel plow to replace or supplement an inefficient wooden plow. It means introducing a little better cultivating or threshing implement. We need engineers with the vision and the ability to work out and adapt these simple improvements that the people themselves can apply with their own resources.

Food Engineering: In most underdeveloped areas, harvest time is feast time; the rest of the year is hungry time. The people have no way of conserving food in order to tide them over to the next harvest. In the United States, we probably lose ten per cent of our agricultural products through spoilage, insect infestation and waste. In some countries, the loss must be 25 per cent or more. In Africa I have seen millions of cattle, and not a packing plant.

In parts of Costa Rica the farmers can produce two crops of corn a year, but the rainfall is so heavy that the grain sprouts on the stalk, and much of what is harvested is ruined by mold and insects. Point 4 technicians there showed the farmers how to build a simple corn drier, which resulted almost immediately in better prices for corn and an increase in production. An expert in milling was brought from Kansas for a few months, and as a result of his technical advice, an agency of the Costa Rican government has built modern grain elevators, a quick-freeze plant and cold storage facilities with its own funds. In Peru, a fisheries expert from our Department of Interior is helping the fishermen increase their catch. Another American agricultural engineer has helped construct a cold storage plant in Lima that will assure the people a constant supply of fish at reasonable cost.

Chemical Engineering: Closely related to food engineering is chemical engineering, with the contributions it has made to the food industry. Chemical engineers can make many valuable contributions to the progress of other peoples. The insecticides, weed-killers and the like already in use in our own country, if applied and adapted for use in other areas, can increase the production and utilization of food. I understand that there is a shortage of wood pulp and other material for cellulose products in the industrial nations. Yet in the tropical regions are wide stretches of forests waiting to supply the demand.

Purifying Sea Water

One of the most intriguing possibilities of all is that chemists will devise an economical efficient way to purify sea water by removing the salts, and make that limitless source of water available for irrigating desert places like the Sahara and the west coast of South America. Two things are needed to make this dream a reality: first, practical processes for purifying the water in large volume and, second, cheap power, possibly from atomic energy or solar energy. We must look to engineering for both answers.

Industrial Engineering: An increase in agricultural production naturally leads to industrial development. But it is a step by step process—little industries that eventually lead to big industries. As the people learn to produce more food and as surplus food production frees

labor from the field, raw materials for small industries become available, along with the labor to process them.

This is a gap that needs to be closed in most of the rural countries. I referred to the millions of cattle I saw in Africa, without packing plants to process and preserve the meat, the hides and by-products. The people there, and in comparable areas, don't need large, expensive factories. They need a little local packing plant, a little local shoe factory, a little local textile mill. They don't need vast amounts of capital from outside. They need to *know how* to use their own capital, their own raw materials, their own resources, to produce for their own vast internal markets. An American technician in Bolivia reports that Bolivians have asked him how they might profitably and safely invest a million dollars in local enterprises. There is a job—an almost limitless job—for American industrial engineering in the other regions of the earth.

Architectural Engineering: A house, or a hospital, or a factory, is not just four walls and a roof. It is a product of engineering that plans and constructs each buiding to serve a particular purpose. The underdeveloped countries need the techniques of American designers and structural engineers. They need the advice of our housing experts. And it isn't just a question of exporting our own designs and techniques. We have got to use imagination and ingenuity in the use of local materials to meet local economic, climatic and social conditions that vary widely from country to country. In some countries the best material for housing is bamboo, in others rammed earth may be the best answer, in still others, tile from local clays.

I think these examples cover enough ground to show that it is practical to try to fill the breach in engineering knowledge in foreign countries and that, as I said, the cost of applying technical knowledge to foreign problems is very small considering the progress that results.

Strategic Need for Technicians

The point I would like to emphasize again to this audience is that we must do more than merely send our technicians into foreign countries to supervise engineering projects. In the first place we do not have enough technical men to do the economic development job that needs to be done as fast as it needs to be done. In the second place we are interested in having foreign peoples learn to do their own engineering. It will not be enough merely to provide the technical advice to set up one irrigation system; we want people to be able to build their own. So we must do all we can to expand the corps of trained engineers in underdeveloped areas.

Further we must be imaginative about spreading engineering knowledge and engineering education. We need an imaginative, pioneering approach. The stress that a steel girder of given size will stand is standard but American engineering problems often are not identical with engineering problems in Africa, Asia and Latin America. So we must cooperate with foreign peoples in developing African, Asian and Latin American engineering, using our basic knowledge as the foundation and our imaginations to solve particular kinds of problems the quickest, cheapest and yet most effective way.

I think this society is especially equipped by experience and purpose to help in this process of spreading engineering knowledge and encouraging engineering training. I hope you will work with us to that end. I have no point-by-point program to propose to you. I am merely outlining a problem whose nature will undoubtedly suggest solutions to you if you can spare the time to think seriously about it.

I hope you will be as enthusiastic about solving this problem as I am because I thing the challenge of Point 4 to American engineering is one of the most exciting things that has ever happended to a romantic, though largely unsung, profession.

Judging the Effectiveness of Teaching Aids*

By CARL W. MUHLENBRUCH

Associate Professor of Civil Engineering, Northwestern Technological Institute, Chairman, ASEE Committee on Teaching Aids

After the symposium on teaching aids at the annual meeting of ASEE at Rensselaer in 1949, the author overheard an individual remark, "I still think the best teaching aid is a piece of chalk." This individual was engaged in conversation and shown some of the teaching devices on display, with special reference to the unusual opportunities which they presented to the instructor and the student. The skeptic was apparently convinced. It was with a great deal of pleasure that he informed me at Seattle last year that he had carefully considered the matter and had decided to revise his teaching procedure considerably. This chap is now using colored chalk!

Here is one extreme in a field in which the middle ground is vast indeed. By contrast, there is one school which is considering having several question-asking machines located in the corridors. Each of these machines will have approximately 600 questions contained in its "brain." These will cover a great range of the core subjects in engineering. The student will place an identification card in the machine and attempt to answer the questions as they are presented to him by the mechanical gadget. At the end of a specified number of questions the machine will shut itself off, grade the student, record the date, the number of the machine, the sequence of question numbers, and the percentile score.

Some place in the middle ground between these two extremes there is a teaching aid which can properly be used by an engineering teacher for some particular subject. It is the purpose of this paper to examine this middle ground by looking at the following points:

1. Types of teaching aids
2. Some advantages and disadvantages of teaching aids
3. What can be used as a yard stick for evaluating a teaching aid for a particular instructor and course
4. The cost of producing teaching aids in the engineering college
5. The difficulties of using teaching aids, particularly the motion picture and slide type, in rooms not adapted for the purpose
6. The work of the Teaching Aids Committee of ASEE in reviewing and cataloging teaching aids

First it will be necessary to define the basic function of the teacher. In this paper it will be assumed that the principal job of the teacher is to provide, by means of his presentation, a high order of interest quotient which will get the student to learn. The term "teacher" is thus somewhat of a misnomer since the student must actually teach himself if he is to learn in the full sense of the word. The best way an engineering instructor can motivate his students to learn is by presenting the material in a way that will arouse the students' curiosity so that they will learn and thus gain understanding.

* Presented before the Division of Engineering Drawing at the Annual Meeting of the ASEE, East Lansing, Michigan, June 25, 1951.

Types of Teaching Aids

The entire field of teaching aids was summarized at the 1948 annual meeting of ASEE by Professor W. J. King in a paper titled "Industry-College Cooperation in Developing Teaching Aids."† In this paper Professor King listed fourteen different teaching aids under the general classifications of full-scale models, small-scale models, cut-away samples, small parts and mechanisms, laboratory apparatus, industrial displays, pictorial displays, catalogs, lantern slides, and talks by outstanding leaders of industry. Breakdowns of each of Professor King's classifications can be made and others can be added. This paper refers to all types of teaching aids except lectures by practicing engineers.

Some Advantages and Disadvantages of Teaching Aids

Proponents of teaching aids have often been convicted of being gadgeteers who let their hobbies run away with them. In some cases this is undoubtedly true, but certainly not in all cases. The accusation, however, must be considered. It brings up a very important consideration that every teacher must keep in mind when he judges the worth of any teaching aid for his own use: the device should not be a terminal point in itself. It must set the mental stage for the student by motivating him through interest or curiosity to go on to a full understanding by the working of problems. The device may even be of such a type that the student can actually use it to pose and solve problems. In the case of a motion picture of a turbine, for example, the student could be shown how the turbine is assembled, how it operates, and how some variables influence its operation. The use of the film should not be limited to this point insofar as teaching is concerned. The student should be given problems which bring out some of the points presented in the film and should be made to solve these problems within a few minutes after the film is shown. An excellent idea in films for engineering teaching would be to have the film itself wind up with a question mark by posing a problem which the student would then solve. A most unfortunate circumstance is the use of a device which can be carried to the classroom, demonstrated by the instructor to the amusement and possible edification of the student and then put back in its case and, with a smug smile, carried out of the classroom. Such a device could of course do a job of motivation, but the real true follow-through in the learning process will come by having the student solve problems for complete understanding. Therefore, a teaching aid that can be used by the student to pose and solve a problem is, in the author's opinion, the ideal one.

On the credit side of the ledger, teaching aids are very helpful in undoing incorrect ideas that have become firmly rooted in the mind of the student. They can be used to build carefully on a few fundamentals by a process which can always be repeated (as in the screening of a film, for example) and can be improved from time to time. Many teachers are aware that the illustrations in textbooks are often actually misleading to students. The average engineering student will look at such an illustration and see the complete finished product but is unable to strip it down to its fundamentals or to read the text and follow the manner in which the chart was developed. Of course the teacher in working at the board presents the material in the correct way since he starts with a blank board and through oral and visual presentation develops the entire diagram. This is the way in which it can be done in the film, very often in a time saving way. It is up to the teacher to decide just when the saving of time should stop and therefore just which diagrams should be presented slowly and apparently laboriously, but still effectually, at the board and which should be presented in

†See October, 1948, issue of the JOURNAL OF ENGINEERING EDUCATION, Vol. 39–2, pp. 90–94.

animated form in movies or perhaps by slides. It is reasonable to assume that a few diagrams presented slowly and carefully in motion picture form would make for much faster and more complete understanding of subsequent diagrams presented in their entirety.

It goes without saying that a gadgeteer will let his gadgets run away with him. The good engineering teacher will select teaching aids so that they do things for him that he cannot do for himself or do them in a much better way, thus justifying their use. Teaching aids are not like frosting on a cake to make the course sweet to the student. They may be interesting in themselves but they will not be effective teaching aids unless they satisfy the basic requirements of encouraging and aiding the student to carry out the learning process himself.

A Yardstick for Evaluating a Teaching Aid

What can the engineering teacher do to decide if a certain teaching aid can be used by him for a particular presentation in a certain subject? Questions that come to mind are: whether or not the device is adapted to his particular way of teaching, including his philosophical approach to the subject; whether it will do the job which he hopes it will do; and a host of other complications. Actually the answer is very simple. The teacher merely needs to ask himself whether it wil help him do a better job of motivating the student to learn. To be more specific, the teacher needs to know whether it will do a better job of (a) presenting ordinary information, (b) presenting information that cannot be presented in any other way, or (c) in motivating the student in developing a sense of professional consciousness (or interest in the humanistic-social stem courses).

The engineering teacher finds it necessary to present two kinds of information, descriptive and technical. Teaching aids often offer an advantage in presenting descriptive material by enabling the teacher to present the information more rapidly and more thoroughly. It is doubtful if many instructors are describing the steel making process with a word picture today. It is so much easier to use a set of slides or a motion picture or better yet actually to visit a steel mill. The time consumed in the visual presentation is so much less and so much more efficient and thorough that the word picture cannot compare with it. Very often technical information can be explained in a much better fashion by the use of animation, as, for example, to explain the meaning of a certain formula. Animation may be done by means of models which can be carried to the classroom or it may be done with a motion picture of the model in operation. An advantage of the motion picture is the knowledge beforehand that it will always do exactly the thing that the instructor wants it to. The disadvantage is that the instructor is unable to allow the student to pose problems other than those which have been solved by the model or explained by means of the model in the motion picture. It might be impossible in a classroom presentation to explain what would happen in a centrifugal pump if the speed of the pump was increased or if the length of the impellar vanes was increased. However, this can be done schematically using data which can be gathered and shown very quickly in a film. There will be other cases where the film will not do a complete and proper job of presenting the material, and if it sets up too simple and pat a case, may actually be misleading. Again, each instructor must evaluate every teaching aid to be sure that the device will not be a terminal point in itself. It must lead to something. In order to place emphasis upon the learning process, the device must permit operation by the student or must in some way stimulate him to further study. In this respect the teaching aid itself is actually motivation, although it basically does help speed up the rate of understanding.

Some teaching aids will permit the presentation of information and under

standing that cannot be presented in other ways. The high speed motion picture, referred to as the "time microscope," is well known in the dynamics field. Here the student is able to see certain dynamic effects as they influence the operation of high speed machinery, and he is able to visualize machine design problems in a way that could not be done otherwise. Other examples would be the action inside a furnace, where high temperature would prevent ordinary observation, or perhaps the action in proximity to an explosion or a test to failure. A further possibility is that by means of the teaching aid the student is given a pseudo-experience which could not be obtained by reading text material. This of course is desirable in many subjects.

An important function which the engineering instructor must often perform is to motivate the student to an interest in professional matters or perhaps in the humantistic-social aspects of the engineering profession. This can often be done with motion pictures or slides, as, for example, in showing a long range city planning program where slums are cleared and replaced with more desirable low cost housing. It can be shown quickly how transportation can be improved, and the general welfare of the community benefited, if the engineer plans wisely with an overall humanistic-social and economic consciousness. Such a viewpoint is difficult to present in textbooks.

To repeat once more the second point of this paper, the student will remember longer what he sees if he is able to put it to some quantitative use shortly after seeing it. Avoiding the use of the teaching aid as a terminal point and stressing the actual learning process makes for a higher retentivity.

The Cost of Producing Teaching Aids

Many college teachers wishing to make their own motion pictures have been discouraged by the $25,000 to $50,000 cost of a 20 minute industrially sponsored film. It is doubtful if any school could afford such an amount. Actually, however, it is possible to produce creditable and very effective silent films in color of 20 minute showing for $300 in student labor and supplies. The author has produced such a film with about 22 minutes showing time on the subject of "FATIGUE—The Failure of Materials Due to Repeated Loading" for an actual cost of $276. This did not include a charge for personally owned photographic equipment or for space or other overhead charges. A sound track could be added to the film by a professional narrator and one print provided for approximately $300. This cost can be reduced by recording the narration and musical background on tape and supplying this to the commercial firm making the sound on film print. With equipment and space at hand it is therefore possible to produce a sound film in color for 20 minutes showing at a cost of approximately $500 to $750.

The author introduces animation into a motion picture by means of simple cardboard cutouts that are schematic representations of mechanisms and other devices. The device shown in Fig. 1 is used to show ballast "pounding" under a railroad rail and the resultant bending of the rail. The rail is fastened to long wooden handles at each end. These are pivoted to allow the rail to be bent. Ballast, in the form of one-half inch top size crushed limestone, is placed around the ties. The wheel is painted on the back with rubber cement so that it will "roll" along the rail when pulled over the neutral background by a handle attached to the wheel on its bottom side. The camera sees only the rail, ties, ballast and about 40 per cent of the lower part of the wheel.

The development of a transverse fissure in the head of a rail can also be explained very effectively with animation. A cardboard cross-section of a rail is painted black and is shown to have a small inherent defect represented by a white dot. This defect is made to increase in size through the use of many single frame

FIG. 1. Cardboard cutouts for motion picture animation used to represent bending of a railroad rail under a rolling load. Wood handles fastened to the cardboard at A and B are pivoted to permit application of bending moment. Wheel is 15 in. in diameter.

FIG. 2. High speed stamping mechanism model for motion picture. Forming head, connecting rod and flywheel are moved slightly between single frame exposures.

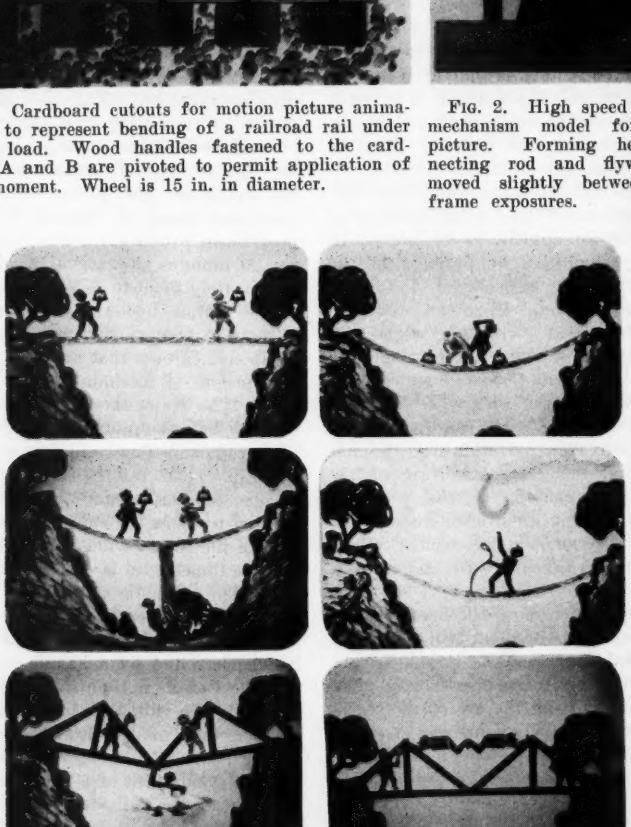

FIG. 3. Individual frames from sound-slide film "Lines of Force." Characters are colored red for tension and blue for compression. Film develops a concept of lines of force in trusses. Reference to "sky hooks" and other ridiculous situations is an attempt to promote interest.

exposures, the dot being enlarged slightly each time. The full size fissure is finally compared with an actual one closely resembling it in size and shape.

A model of a high speed stamping mechanism is shown in Fig. 2. Animation with this device is accomplished with single frame exposures, moving the parts slightly between each exposure.

All of the author's animation models are made of heavy poster board (cardboard). They are painted with show card colors in pastel shades. These paints are completely flat so that there are no annoying highlights to cause photographic difficulties.

The cost of making slides is so small the author does not consider it worth discussing here. A good quality 35 mm. camera with a copying attachment should be available for staff use in every department. Slides in black-and-white or color can be made with such an outfit for a very low unit cost. Some figures used in producing a sound-slide film "Lines of Force" are shown in Fig. 3.

Production of models to illustrate fundamental scientific and engineering principles need not be tedious or expensive. Elaborate devices are seldom as effective teaching aids as simpler versions. The reader is referred to the following articles on this subject which appeared in the JOURNAL of ASEE:

"Demonstration Models—Their Use and Construction," Hartenberg, R.S., April, 1950, Vol. 40, No. 8, pp. 430–434.

"Exhibit of Teaching Aids at the Seattle Meeting," Lutz, S.G., March, 1951, Vol. 41, No. 7, pp. 406–408.

"A New Aid in Teaching Kinematics," LaJoy, M.H., and Larsen, O.M., May, 1951, Vol. 41, No. 9, pp. 542, 543.

"Visual Aids in Education," Shilts, W. L., December, 1950, Vol. 41, No. 4, pp. 235, 236.

Difficulties in Using Teaching Aids in the Classroom

Most engineering teachers have at one time or another had the usual bout with inverted slide images, improperly darkened and inadequately ventilated rooms, balky projectors, and a host of other evils. Most of these can be overcome by assigning a custodian to the operation and maintenance of visual equipment. A few classrooms can be set aside for projection and designed to prevent lighting and ventilation difficulties. A most unusual classroom for this purpose was designed for New York University by Dr. S. G. Lutz and was described briefly in a spring, 1950, issue of *Life* magazine. One feature of this room is the use of a hand operated supersonic whistle to actuate the slide projector by remote control, thus freeing the instructor to use a pointer or to supplement the slide with the blackboard.

Models should be stored in a convenient place where all instructors can get to them. They should be adequately maintained. In some cases it may be feasible to assign all classes in a subject to one classroom where models, charts, diagrams, and other teaching aids can be conveniently stored for ready use by the instructor.

The Work of the ASEE Committee on Teaching Aids

Several years ago the Division of Educational Methods appointed a sub-committee to study the problem of teaching aids in the engineering colleges and universities. Much of the committee's present activities are concerned with publishing a catalog of teaching aids for use by any one desiring information regarding the devices which are available. This catalog will be sold at nominal cost and will contain information as to where the teaching aid may be obtained, its dimensions and other physical characteristics, any charge involved for its use, and other detail information. The listing will also include a brief description of the device and a review of it prepared by a committee of three qualified educators in the field covered by the teaching aid. The reviewers' comments will indicate, for ex-

ample, the amount of the material that is considered to be advertising (in case the teaching aid was produced by commercial interests), the year level at which the material could be used, the general quality of the narrative explanation used in presenting the material, amount of theory or application, and other pertinent information. The object of the listing of the teaching aid in the catalog would be to enable the potential user to determine the worth of the material and of course to permit him to accept this information in good faith with the assurance that it was prepared by competent individuals. The completion of this catalog will do much to enable engineering teachers to determine the worth of teaching aids in their course presentation.

In order to carry out this reviewing plan the committee is currently raising a fund of $7000 which will be used to pay the major part of the expenses of preparing and publishing the catalog. As this is being written, three-fourths of this amount has been received and it is expected that the remainder can be raised without difficulty.

College Notes

F. W. Tatum, Professor of Electrical Engineering, **Southern Methodist University**, has been named Chairman of the Department of Electrical Engineering at S.M.U. Professor Tatum received his technical education at Columbia University, with degrees of B.S. in E.E. and M.S. in E.E. From 1935 to 1947 he was associated with the American District Telegraph Company and held the position of Engineering Supervisor at the time of his resignation to join the faculty at S. M. U.

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Cornelius Wandmacher, present director of the evening session and associate professor of civil engineering at the Polytechnic Institute of Brooklyn, will become the William Thoms professor of civil engineering and head of that department in the **University of Cincinnati** College of Engineering.

. . .

William A. Edson has been named director of the school of electrical engineering at the **Georgia Institute of Technology**, it was announced by J. W. Mason, dean of engineering, Dr. Edson, who until his recent promotion served as professor of electrical engineering in the school, will replace Dean D. P. Savant who retired as director in July of this year after almost 30 years of loyal service.

Report of the Committee on Atomic Energy Education

Summary of Activities—May 23, 1951

By HENRY ARMSBY

Chairman, ASEE Committee on Atomic Energy

The Committee has held two meetings: on June 2 and 3, 1950, and on May 8, 1951. Regional sub-committees have been formed under the chairmanship of five committee members associated with five major operating centers of the Atomic Energy Commission throughout the U. S.

The Northeastern Regional Sub-committee sponsored an inspection tour for ASEE members at the Brookhaven National Laboratory on April 7, 1951. The ASEE Midatlantic Section meeting at Rutgers on May 12, 1951 was devoted to nuclear engineering education. The Allegheny Section at Carnegie Institute of Technology on April 21, 1951 conducted a panel discussion on the subject on nuclear engineering education.

The Southeastern Regional Sub-committee arranged for five papers on atomic energy to be given at the Fontana Conference on August 28, 29, and 30, 1950 and four atomic energy papers at the Biloxi Meeting of the Southeast Section of ASEE on March 22, 23, and 24, 1951. The Sub-committee is sponsoring a symposium at the Oak Ridge Institute for Nuclear Studies from August 27 to September 6, 1951 under the title of "The Role of the Engineer in Nuclear Development."

The Northwestern Regional Sub-committee sponsored an ASEE Conference at Hanford on February 8 and 9, 1951. Sub-committee members were given a thorough description of Hanford facilities and a tour of the plant. The Southwestern Regional Sub-committee was formed as the result of the ASEE Conference held at Berkeley on December 15–16, 1950, the program of which was devoted to nuclear energy education. Arrangements were made to hold a meeting to organize the Middlewestern Regional Sub-committee at the national convention of ASEE on June 27, 1951.

Certain points of agreement among engineering educators have become evident as the result of these regional meetings. In considering nuclear engineering education all of the groups have stressed: the need for developing competence in basic science, the need for training in human engineering, the need for developing the ability to reach sound economic judgments, the continuing need for fundamental training in recognized major fields of engineering, the desirability of reserving specialized training in nuclear engineering for graduate study, and the importance of continued university-sponsored technical training for engineers working on the national atomic energy program, all within the framework appropriate to the individual engineering school concerned.

At regional conferences AEC representatives have discussed the availability of source materials for nuclear engineering education. On the basis of such discussions the Committee has made two recommendations to the AEC.

a. That the AEC prepare a bibliography of basic materials which would be

of particular interest to engineering educators, for publication as a joint enterprise of the ASEE—AEC—Office of Education. The AEC has agreed to prepare such a bibliography.

b. That AEC sponsor the preparation and publication of a *Sourcebook on Atomic Energy Engineering,* along the lines of Dr. Samuel Glasstone's *Sourcebook on Atomic Energy.*

The Committee feels that there is much more work to be done and is soliciting comments and reports of activities in this field from members of regional subcommittees and all others interested in nuclear engineering education. The Committee chairman will prepare this material in suitable form for circularization to engineering educators. The Committee plans to meet again in May 1952.

College Notes

William G. Van Note, 45, of Raleigh, N. C., will be the ninth president of **Clarkson College of Technology.** The announcement was made today by Ralph S. Damon, president of the Clarkson board of trustees and of Trans-World Airlines, Inc. Van Note is director of the Department of Engineering Research and professor of metallurgy at North Carolina State College, Raleigh. As president of Clarkson he will succeed Jess H. Davis who will become president of Stevens Institute of Technology.

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The appointment of G. R. Fitterer as dean of the Schools of Engineering and Mines at the **University of Pittsburgh** was announced by Dr. R. H. Fitzgerald, chancellor. Fitterer has been professor and head of the department of metallurgical engineering since 1939. He graduated from the Rose Polytechnic Institute in 1924 and during the remainder of that year worked as metallurgist for the American Chain Co. in Terre Haute, Ind. During the next two years he was employed as metallurgist for the Stanley Works in New Britain, Conn.

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Richard F. Shaffer, Associate Professor of Chemical Engineering at **Pratt Institute,** has been appointed Head of the Department of Chemical Engineering, Dean Nelson S. Hibshman announced today.

Lamme Award

The Committee on Lamma Award is always anxious to get nominations for the Award from the membership of the Society. Any member may place a name in nomination; the selection will be made by the Committee by letter ballot.

About March the first each year, the Chairman of the Committee requests nominations from the Committee, and the result is a list of about twenty-five names. By March fifteenth the balloting begins in order that the selection may be made well in advance of the annual convention.

Until February 1, 1952, the Chairman will receive formal nominations from members of the Society. This closing date is fixed in order that names, and accompanying biographies, may be placed in the hands of the Committee members by March first. It is very desirable that nominations be accompanied by a brief statement made according to the outline suggested below.

A number of years ago the Committee set up the following rules for making the Award:

1. Achievements which can be taken as proof of excellence in teaching or as having contributed to the art of technical training will be given major consideration.

2. Only those achievements will be considered which seem to have the possibility of lasting influence or which have sufficiently stood the test of time.

3. Books, articles, contributions to method and research, which have a beneficial effect upon the teaching of engineering, will be given considerable weight in making the decision.

4. Participation in the work of Engineering and Educational Societies is not necessary for eligibility. Such participation, however, will be given due consideration if it has led to definite and recognized results in bettering technical education.

5. Achievements outside of the field of teaching, such as employment in industry, consulting work, inventions, etc., will be considered as of secondary importance in making the Award.

6. Administrators in engineering schools are eligible. Only that work of Administrators, however, will be considered which has led to definite and recognized improvements in method of teaching or in the art of technical training.

7. Emeritus Professors are eligible.

8. Nominations should emphasize the contributions of the candidate to these major objectives. Concise statements of achievements are much more valuable to the Committee than a series of recommendations from former students and present acquaintances. Listings in "Who's Who in Engineering," and such publications, give some information regarding achievements but material of this type will not give the Committee the needed information to make a valid judgment.

In preparing a biography of a nominee the following outline should be helpful:

1. Preparation for teaching work—school, year graduated, degree, post-graduate work, honorary degrees.
2. Accomplishments as a teacher.
3. Advancement of the art of technical training—books, articles, contributions to method, research, etc.
4. Administrative work in engineering schools.
5. Membership and participation in Engineering and Educational Societies.
6. Engineering practice—employment in industry, consulting work, inventions, etc.
7. Other achievements.

Nominations should be sent to the Chairman of the Committee, Nathan W. Dougherty, University of Tennessee, Knoxville 16, Tennessee by February 1, 1952.

The George Westinghouse Award

The George Westinghouse Award is an annual award established in 1946 by the Westinghouse Educational Foundation to recognize and encourage outstanding achievement in the teaching of students of engineering. The award consists of $1000, together with an engraved certificate. The recipient is selected by a ten-man committee, nine of whom are appointed by the President of the Society. There is also a representative from the Foundation. The Award for 1952 will be presented at the banquet of the annual convention at Dartmouth College, Hanover, N. H., June 23–27, 1952.

The recipient of the Award must have made a significant contribution to the teaching of engineering students and shall have distinguished himself in several of the following ways:

1. Record as a teacher. (Evidence of superior teaching and guidance of students as demonstrated by records of former students, indications of unusual subject matter competence, etc.)
2. Improvements of the tools of teaching. (Textbooks and student notes, descriptions of special courses or curricula, diagrams and models, new laboratory and teaching equipment, etc.)
3. Other activities contributing to the improvement of teaching. (Material relating to the development of teachers in the nominee's department or teachers in general, the development of testing and guidance program for students, the promotion of cooperation with other types of educational units or with industry, coordination of fields of subject matter, etc.)
4. Evidence of high intellectual capacity. (Brilliance of mind as manifested by contributions to literature, degrees and honors received, etc.)

The Award has been established to encourage younger men who have shown by their past record evidence of continuing activity as superior teachers. To them the Award may serve not only as a reward but as an incentive toward further achievement.

In order to achieve this intent, it is deemed essential to limit the Award to those who have not reached the age of 45 by the date of the annual presentation.

Nominations may be made by any person, organization, or group and are to be submitted before February 1, 1952, to the Chairman of the Committee on Award, Dean R. E. Vivian, University of Southern California, Los Angeles 7, California. Nominations must be made on forms available from either the chairman of the Committee or from the Secretary of the Society. Nominations should be accompanied by significant evidence supporting statements and claims.

A Theory of Work Habits of Industriousness*

By WILLIAM C. KRATHWOHL

Director of Tests
Institute for Psychological Services, Illinois Institute of Technology

The work habits which are to be discussed are confined to those of industriousness and indolence.** The theory concerning these work habits is that by means of aptitude and achievement tests in some area a number can be assigned to an individual, called his index of industriousness, which will measure his industriousness in that area.

It should be noted that habits of industriousness are relative instead of absolute and hence with any definition of these traits there must be associated a group with which the individual is compared. Thus a person who would be considered an industrious individual in some activity in the tropics might be considered indolent if he were compared with people in the temperate zones.

In order to test this theory of work habits, it was tried out with a group of 1255 engineering freshmen at the Illinois Institute of Technology in the field of mathematics. To find out what was expected of them, they all took the Iowa Mathematics Aptitude Test, Form M when they entered the Institute. To find out what they had accomplished they all took, during the same week, a locally prepared achievement test called the Mathematics Preparation Test, on the algebra which they had studied in high school. It was assumed that the difference between the scores which they received on these two tests measured their industriousness for mathematics.

In order to make the scores comparable, a linear transformation was used on each set of scores so as to make each mean equal to 20 and each standard deviation equal to 4. Such scores have come to be known as derived scores. They can easily be transformed into standard scores having a mean of 50 and a standard deviation of 10 by multiplying the derived scores by 2½.

Definitions

It was expected that students who made, for example, a score of 22 on the Mathematics Aptitude Test would make approximately a score of 22 on the mathematics achievement test, but in general students did not make the same score on both tests. The difference of a student's derived score on the mathematics achievement test minus his derived score on the mathematics aptitude test was defined to be his index of industriousness for mathematics.

Other definitions which we need are those for industrious, normal and indolent individuals. An industrious person is defined to be one who accomplishes more than is expected of him because of the extra effort expended. whereas an indolent person is defined to be one who accomplishes less. This leaves a third category, that of the normal individual,

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** For conciseness and also to avoid awkward construction, the word indolence as employed in this investigation is used not in a derogatory sense, but rather as a substitute for under-achievement. In the same way, the word industriousness is used as a substitute for over-achievement.

who does about what is expected of him.

The next question was how to define industrious, normal, and indolent students in terms of these indexes. The rule which was used was the one commonly employed in some fields of statistics, that the middle half of a group should be considered average or normal whereas the highest and lowest quarters should be considered above average and below average, respectively. Such a separation meant that students in the upper quarter of the indexes of industriousness for some subject were considered industrious in that subject with their indexes of industriousness ranging from plus 3 and up. The middle half, which had indexes from -2 to plus 2, were considered the normal group. The lowest quarter having indexes of -3 and less were defined to be indolent in mathematics.

The question now becomes, do indexes of industriousness really measure work habits? If they do, they should satisfy the properties usually associated with work habits.

Postulates of Industriousness

One of these properties is that for the same degree of brightness in mathematics, a group of industrious students in mathematics should receive on the average higher grades in some mathematical subject such as college algebra than the normal group, and the normal group should receive higher grades on the average than the indolent group. This property was found to be generally true is an investigation by Krathwohl (3) who found that the average grades in college algebra for each level of brightness for the industrious groups were always higher than were those for the normal groups. Furthermore, these differences were significant at the 1% level or better for all degrees of brightness with the exception of the group which had the highest average mathematics aptitude score and the two groups who had the lowest mathematics aptitude scores. These three groups were handicapped by the grading system because on an ABCDE grading system, a bright student cannot make a grade higher than A no matter how industrious he is and a student with low ability in mathematics cannot make a grade less than E. In spite of such a handicap, the difference for the brightest industrious group and the brightest normal group was significant at the 9% level and the differences for the two groups with the lowest ability were significant at better than the 5% level.

When the normal and indolent groups were compared, the normal groups still received, on the average, higher grades than the indolent group but the differences were not significant at as high a level. Evidently some members of the indolent group reformed, but not very many. The consistent differences between industrious, normal, and indolent groups when compared at the same level of mathematical aptitude indicated that these indexes of industriousness undoubtedly were a function of work habits.

Persistence

A second property of work habits is their persistency. It has often been said by instructors that students who are industrious at the beginning of their college course usually remain industrious, whereas indolent students rarely reform. This persistence of work habits was verified with the experimental group as shown above, because the indexes of industriousness were computed at the beginning of the freshmen year, whereas the college algebra grades were received from five months to ten months later.

Effect on Achievement

A third property which is expected of work habits is that, for a given degree of brightness, the harder a student works, the greater should be his achievement. Indexes of industriousness for mathematics have this property as was found in another investigation (4). To show that increased industriousness was accompanied by higher grades, correlation coefficients were computed between

TABLE 1

CORRELATION COEFFICIENTS BETWEEN GRADES IN COLLEGE ALGEBRA AND INDEXES OF INDUSTRIOUSNESS FOR MATHEMATICS

N	Mathematics Aptitude	r	Confidence Level	N	Mathematics Aptitude	r	Confidence Level
84	27	0.49	1%	125	21	0.42	1%
76	26	0.45	1%	128	20	0.35	1%
121	25	0.51	1%	85	19	0.30	1%
157	24	0.48	1%	65	18	0.27	3%
186	23	0.49	1%	65	17	0.33	1%
163	22	0.42	1%				

college algebra grades and indexes of industriousness for mathematics for each level of brightness in mathematics. These correlations are shown in Table 1.

In this table the column headed N gives the number of students in the group. The column headed Mathematics Aptitude gives the derived score on the Mathematics Aptitude Test, which measures the brightness of the group in mathematics. The column headed r gives the correlation coefficient between grades in college algebra and indexes of industriousness for mathematics. The column headed Confidence Level gives the level of confidence of the correlation coefficient. Thus a confidence level of 1% means that the correlation coefficient being considered could have happened by change less than once in a hundred times.

It is seen from Table 1, that all of these coefficients are positive which means that the higher the index of industriousness for a given level of mathematical brightness the higher, in general, is the grade received in college algebra. Furthermore, with one exception, these results are significant at better than the 1% level, which means that these coefficients could have occurred by chance less than once in a hundred times. The one exception for a derived score of 18 could have occurred by chance 3 out of a hundred times. Evidently indexes of industriousness for mathematics, as here defined, do satisfy the property that for a given degree of brightness the achievement of a student in college algebra increases with his industriousness. If it did not, all of these correlation coefficients would have been zero or negative.

It is seen from Table 1 that the correlation coefficients for the less bright students are lower than those for the brighter students, which is a fact that has frequently been found in these investigations. It seems that students with low ability are a much more unpredictable group than bright students, and they seem to be much more variable on the whole in their work habits than are bright students. Some are highly motivated to do as good work as they can. Others just do not care as long as they get through. Furthermore, these low ability students are handicapped in that there apparently is a ceiling for low ability students beyond which they are unable to rise no matter how hard they work.

English Compared with Mathematics

For a further test of the validity of indexes of industriousness, as here defined, to measure work habits, another subject, English, was chosen because it is quite different from mathematics. The experimental group consisted of 308 sophomores at the Illinois Institute of Technology who took a vocabulary test as an English aptitude test and the Cooperative Mechanics of Expression Test as an English achievement test when they entered the Institute as freshmen. From these two tests their index of industriousness for English was computed. At the

end of their sophomore year these same students took the sophomore English Expression Test, which is published by the Cooperative Test Service. The results obtained by Krathwohl (5) with the subject of English paralleled closely the results with mathematics. The groups who were rated as industrious at the beginning of their freshmen year received higher average grades in English Expression one year and eight months later than did the normal groups, and this was uniformly true whether they were above average, average or below average on their vocabulary scores. On the other hand, the groups who were rated as indolent at the beginning of their freshmen year still were doing poorer work than the normal groups one year and eight months later.

There was, however, this variation: that whereas the difference for English achievement between the normal and the indolent groups for the students who were above average in vocabulary was significant at the one per cent level of significance, the difference between the normal and indolent groups for the students who were average in English vocabulary was significant at only the five per cent level. Evidently some reformation had taken place, but not much. Furthermore, no comparison could be made in English achievement between the normal and indolent groups for students who were below average in English vocabulary because there was only one student left in the below average indolent group and he was dropped in June.

Ability to Stay in College

This surprising result, that only one student was found in the below average indolent group in English at the end of the sophomore year, was very interesting because it is at variance with the opinions of some engineering instructors who claim that is does not matter what a student does in English as long as he is doing satisfactory work in mathematics, physics, chemistry and engineering subjects.

Similar to the results obtained in English for the ability to survive, were the findings obtained for mathematics. At the end of the freshmen year there were no low ability indolent students in mathematics left in the class, although the theoretical number remaining in this category out of 1255 students should have been 78. In other words, about two years in English or one year in mathematics is the limit of time that low ability indolent students can remain in an engineering school.

The property that the harder a student works in English the higher will be his grade, also turned out to be true. For each level of brightness in English, as measured by vocabulary, the correlation coefficients were positive. Every correlation coefficient was significant with the exception of the group with the lowest scores on the vocabulary test. Both this group, who were the least bright in English, as well as the groups previously mentioned, who were least bright in mathematics, turned out to be somewhat unpredictable. One possible reason for the uncertainty connected with them is that some of the low ability normal students have changed their work habits. Note that there were practically no low ability indolent students in English. A more plausible reason is that similar to the results in mathematics, the low ability group in English are handicapped by a ceiling which sets a limit to their success no matter how industrious they may be.

Average Indexes

An interesting result was found with both the mathematics and English groups when the averages of indexes of industriousness were computed for each level of brightness. It was found that the average index for the brightest students was always negative and the average index for the students with lowest ability was always positive. At first glance it would seem that bright students, as a whole, tend to be indolent. Such a conclusion, however, is not warranted. The reason for this divergence in the averages of indexes of industriousness be-

tween low ability and high ability students is that indexes of industriousness are relative and therefore students of low ability apparently have to work so hard in order to survive that the bright students are made to appear indolent by comparison.

Because the investigations for two such different subjects as mathematics and English gave evidence to justify the hypothesis that indexes of industriousness were measuring work habits, a study was made for English (6) of the relative contributions of vocabulary and an index of industriousness for English to achievement in English. It was found that if the group were taken as a whole, the indexes of industriousness contributed very little to achievement in English. If, however, the original group was divided into subgroups, quite a different picture appeared, and the effect of indexes of industriousness varied greatly for the different subgroups. For instance, when the original group was divided into three subgroups on the basis of being above average, average, or below average in vocabulary, then the index of industriousness or, in other words, work habits, contributed more to achievement than vocabulary, and better predictions for achievement could be made from the indexes of industriousness for English than from the vocabulary scores. If, however, the original group was divided into three subgroups of industrious, normal and indolent students, then vocabulary made the greater contribution by far and the predictions for achievement from the vocabulary scores for each of the three groups were higher than for any other arrangement. In other words, to get the highest possible prediction for English achievement, the best method is to divide the group into an industrious, a normal, and an indolent group and then predict English achievement separately for each group from the vocabulary scores. Incidentally, of the three groups, the best prediction for achievement in English was made by the industrious group.

Similarity to Social Habits

This finding that the predictions of achievement in English could be predicted much more accurately for the industrious group than for any other group is remarkably similar to the results obtained by Hartshorne and May (2) in their studies of social habits such as honesty, truthfulness, and morality. They found that if a man possessed the more desirable qualities, in general, he was apt to be more consistent. If, on the other hand, he possessed the more undesirable qualities, in general, he was apt to be more inconsistent. The man who is generally honest is also consistently honest, which means that he is dependably honest, whereas the man who is generally dishonest is apt to be inconsistent—he may be honest in one situation and dishonest in another.

A similar investigation was made for mathematics (7) to find the relative contribution of mathematics aptitude, and an index of industriousness for mathematics, to achievement in mathematics. The results for mathematics paralleled very closely those for English. The only exception was that correlation coefficients for mathematics were lower than were those for English, due to using instructors' grades instead of an objective examination. Otherwise, the general conclusions were the same.

Independence of Work Habits

These investigations naturally brought up the question whether work habits were specific or general. That is to say, whether it would follow that a student who was industrious in mathematics would also be industrious in other subjects. The same group of 308 sophomores was used by Krathwohl (8) to investigate the independence of the indexes of industriousness for English, chemistry, mathematics and physics. Out of the 6 pairs that it was possible to form from these four subjects, it was found by means of the chi square test that 5 of the pairs were independent of each other.

The sixth pair, chemistry and mathematics, were found to be dependent on each other. However, when correlation coefficients were computed for each pair, the correlation coefficient between the indexes of industriousness for mathematics and chemistry was found to be only 0.35, yet statistically significant. Such a low but significant value of the correlation coefficient means that a relation does exist but it is a small one. All of the remaining five correlation coefficients were, as expected, much lower and none of them were statistically significant. The conclusion to be drawn from this investigation is that a student can at one and the same time be industrious in mathematics, normal in English and indolent in physics.

Again these results follow very closely those obtained by Hartshorne and May (2) in their studies of social habits such as honesty, truthfulness, and morality. They found that these social habits were specific instead of general. That is to say, we cannot speak of an honest man, but rather of an honest act. For instance, a man may be honest in his income tax returns, but dishonest when he fails to return to the lost and found bureau an article which he has found. In like manner, we cannot speak of an industrious individual, but rather we must say that an individual is industrious in some one area of activity, whereas he may be indolent or normal in another.

The slight dependence between work habits of mathematics and of chemistry demands further investigation, possibly a repetition of the experiment on another group of engineering students.

Before drawing conclusions which are too general it should be remembered that all of the students in these studies were engineering students, who are known to have quite different characteristics from other pre-professional students, as shown by Fairbairn (1). For instance, she found by means of a questionnaire that 36 per cent of the pre-law, 29 per cent of the pre-medical, but only 7 per cent of the pre-engineering students indicated that as children they had liked to dress up for parties, whereas 13 per cent of the pre-law, 16 per cent of the pre-medical and 72 per cent of the pre-engineering students replied that they liked to talk with their inferiors. Hence, further investigations on the properties of these indexes should be made on other types of students, particularly those from liberal arts colleges.

The theory of work habits as outlined in this article has certain weaknesses and certain advantages. The principal weakness in the theory is that with the usual commercial tests the spread of scores of the achievement and aptitude tests, which are used to measure the indexes of industriousness, are approximately equal. Hence, the brightest students in a group cannot get a higher index of industriousness than zero, and the least able students cannot get one less than zero. The simplest method to overcome this weakness of the equality of the spread of scores is to make the difficulty of the initial achievement test sufficiently great so that the spread of scores of the initial achievement test will be greater than that of the aptitude test. There are other methods which can be used to measure indexes of industriousness for students in the extremes of the frequency distribution for aptitudes, but they are more complicated.

Ease of Securing Information

The great advantage of the present theory is the ease with which a counselor can secure information concerning the work habits of a student from his test scores. Making two assumptions, (1) that the theory for indexes of industriousness holds for other subjects in addition to those already investigated, and (2) that the scores which a counselor uses are local ones with equal means and standard deviations; then all he has to do is to pick out an achievement test and an aptitude test and, by simply finding the difference between the two scores, he can ascertain if a student is industrious,

normal or indolent in a particular subject, and the degree to which a student possesses these traits.

The following conclusions can be drawn from these investigations:

1. By means of aptitude and achievement tests in some field, it is possible to assign a number to an individual which will measure his industriousness or indolence in that field.
2. It is possible to show statistically that work habits do affect achievement. Such a statement means that, in general, other things such as level of brightness being equal, the harder a student works, the higher his grade will be.
3. There is a tendency for industrious and indolent work habits to persist certainly over as long a period as two years. Such information should be particularly valuable to counselors.
4. Work habits tend to affect the ability of a student to remain in college. For instance, no matter how bright or industrious a student in the experimental group might have been in his engineering subjects, if he had a small vocabulary and was indolent in English, he was unable to survive through his sophomore year. Similarly, no low ability indolent student in mathematics was able to survive through the freshman year.
5. Work habits of industriousness act very similarly to the social habits of honesty, truthfulness and morality, which were investigated by Hartshorne and May, in that they are specific instead of general, so that a person who is indolent in one field may not necessarily be indolent in another. In particular, a person may be industrious in mathematics normal in English and indolent in physics.
6. Work habits of industriousness also act very similarly to social habits, in that the possession of desirable qualities is accompanied by increased consistency and predictability, whereas the possession of undesirable traits is accompanied by inconsistency and reduced predictability.

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Graduate Work in Machine Design*

By R. R. SLAYMAKER

Professor of Machine Design, Case Institute of Technology

and D. K. WRIGHT, JR.

Associate Professor of Machine Design, Case Institute of Technology

Before attempting to write specifications for a graduate program in Machine Design, let us first review the objectives of the usual undergraduate course. Undergraduate Machine Design is the one subject which makes use of all previous courses. It is, perhaps, the first opportunity the student has to see his educational puzzle begin to fit together. In Machine Design he can see the why of descriptive geometry at the same time that he sees the effectiveness of calculus, and he begins to realize that a knowledge of statics and dynamics is a "must." He finds that strength of materials and metallurgy go hand in hand and that fluid mechanics has more use than the mere satisfying of college degree requirements. In Machine Design the student learns that a firm theoretical core is necessary but that he must surround that core with a ring of practicality and that his work will be for naught if his design cannot be built or will not operate. He learns that there are times when rough approximations are more desirable than rigorous analytic solutions and that there are others in which a compromise may be costly and even disastrous. He discovers that in Machine Design there is no "right answer," for no machine exists that cannot be improved; but he finds that there are certain limits between which he must operate and that more often than not, cost will dictate where he must stand between these limits.

Subject-wise, the student meets nothing new in Machine Design. He simply applies what he has already learned. Briefly speaking, undergraduate Machine Design gives the student an opportunity to view his mechanical engineering as a whole instead of in parts. To be still more brief, in Machine Design the student begins to be an engineer.

Who Should Take Graduate Work

Having begun to be an engineer, the student should next have an opportunity to be one. No young man who hopes to be in the design business should take graduate courses *about* design without first having been *in* design. With some experience behind him, the young designer is in a better position to know what kind of advanced study he wants or whether or not he needs more academic work at all. Not all design is analysis and not all designers can be improved by a college. An SR4 strain gage is no substitute for ingenuity, and the practical know-how of a die designer cannot be enhanced by elliptic integrals. We will probably all agree that ingenuity, while it can be developed, can never be taught and that "know-how" cannot be compressed into a three-hour course.

Graduate work in Design has then, by common consent, become analysis. This means that only analysts or men who could profit by analysis should be in our

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graduate schools. Rarely does one find a man who enjoys analyzing a machine's characteristics who is also willing or able to spend much time inventing something to analyze. How many ways to make a "widget," pick it up, turn it over, fold it or package it—do not, it seems, go along with a desire to work with pounds per square inch horsepower, feet per second or Reynold's numbers.

We conclude therefore that graduate work in Design is for men with some experience † not boys with "graduate-schoolitis," and that the men are interested in and will be associated with analysis. Knowing the type of individuals with which we have to deal, the next step is to examine their educational backgrounds and provide a program which will fill their needs.

What Background Is Essential

The mechanical engineering graduate enrolling in a Machine Design Master's program may be expected to have the following undergraduate training in pertinent subjects:

One year of engineering mechanics, including statics and dynamics.

One-half year of strength of materials, including laboratory.

One-half year of kinematics of machines.

One year of design of machine elements.

Mathematics through differential equations.

One year of thermodynamics, of chemistry, and of electricity.

Graduates in other engineering fields or those having deficiencies in any of these subjects would be required to make them up before being admitted to graduate standing. This list is not unduly restrictive when compared with current mechanical engineering curricula. It is rather a minimum requirement which attempts to balance reluctance to start at too low a level against the desire to include, for example, an electrical engineering graduate whose objectives have been modified by his work. Most mechanical engineers who have studied machine design would have more than met the specification.

Scope of Program and Course Content

The requirements for the Master of Science degree ordinarily include approximately 30 credit hours of study beyond the Bachelor's level including a six to ten credit hour thesis.

In Machine Design the Master's program should offer the student, recognizing tha he is primarily a coordinator and user of technical information rather than a discoverer, an opportunity to consolidate and extend his knowledge, rather than an intensive study of a specialized area.

In view of this objective, the value of a research thesis which uses a large portion of the student's program should be carefully weighed. For the student with minimum preparation, additional courses would probably be more valuable.

The core of the mechanical designer's problems—determinations of force, stress, deflection, wear, motion, vibration—lies in the realm of Mechanics. The course work should, therefore, give the student further study in Strength of Materials and Elasticity, in Kinematics and Dynamics including vibration problems, and in Experimental Stress Analysis. It should also leave him some time for diversification—indeed this should be required—and perhaps some to pursue a particular interest. Courses in materials properties and fabrication—metallurgy and chemistry should be useful, as well as electricity, heat-power, industrial engineering, and servo-mechanisms.

A typical program for a candidate having minimum preparation follows:

†During the 1950–51 year the Machine Design Division at Case served 46 graduate students representing 30 Cleveland industries.

1. *Vibration Problems:*‡ A three or four hour course in vibrations in linear mechanical systems using a text such as Den Hartog, Timoshenko, Thomson, or Freberg and Kemler.

2. *Advanced Strength of Materials:*‡ A three hour continuation of the elementary course taking up the various methods of computing beam deflections, strain energy methods, elastic stability and column action and three dimensional stresses and strains at a point.

3. *Kinematics and Dynamics of Machines:* A four hour critical survey of basic kinematics and dynamics, preferably using the methods of vector analysis and graphical procedures, and their applications to machine analysis. Topics include static and dynamic force analyses, inertia in rotating systems including gyroscopic effects, critical speeds, and cam dynamics.

4. *Problems in Machine Design:* A four hour course illustrating analytical technique in a variety of design situations. The problems are selected to fill gaps left by the other courses and generally stem from the instructor's experience. Subject matter includes hydrostatic and hydrodynamic lubrication with special emphasis on internal combustion engine bearing design; determination of reciprocating engine rod and main bearing loads; involute trigonometry as applied to gear design and the practice of pyramiding, and to involute splines and measurements for inspection; a thorough study of the ASME Shaft Code for the purpose of reviewing strength of materials with an application to the design of a toggle type impact extrusion press; stress and deformation studies of parts made at room temperature but used at both high and low extremes; fluid couplings and torque converters with emphasis on the matching of a converter to an engine—etc.

5. *Applied Elasticity:* A three hour course using the second volume of Timoshenko's "Strength of Materials" as a text and including the subjects of beams on elastic foundations, bending of thin plates, curved beams, torsion, and contact stresses.

6. *Experimental Stress Analysis:* A four hour course in the most important experimental methods, including two and three dimensional photoelasticity, brittle models and lacquers, mechanical and electrical strain gages, and membrane analogy method. The importance to machine designers of the use of electrical methods for force and vibration measurements is to be emphasized.

7. The remainder of the student's program is composed of either thesis or course work and is arranged in consultation with his advisor to serve best the student's objective. This might include a minimum of eight credit hours for the student with minimum preparation to a maximum of about fifteen hours by one who had majored in machine design as an undergraduate, and who might have taken as senior electives either Vibration Problems or Advanced Strength of Materials, or both.

It is evident that the minimum preparation student, to obtain the desired diversification, should schedule course work rather than thesis. These courses could be chosen from a list similar to the following:

Advanced Heat Power Analysis,
Electronics,
Machine Analysis,
Mechanical Analysis of High Temperature Machinery,
Metals and Alloys,
Methods Engineering,
Physical Metallurgy,
Plastics,
Servomechanisms or Automatic Controls,
Statistical Quality Control.

The better prepared student might be permitted to elect a thesis as part of his program. A flexible policy with regard to length of the thesis project is sug-

‡ Open to undergraduates majoring in Machine Design.

gested. Problems might be rated at from three to nine hours credit based on the faculty advisor's estimate of the amount of work required.** Thus, one student's program might call for a nine hour thesis, and another's (a student who would benefit more from course work) for a three hour thesis and two courses.

Advanced mathematics as such has been purposely omitted. Mathematics courses will certainly do the student no harm but it is our feeling that the type of student who is interested in Machine Design is more receptive to applied mathematics. He learns something tangible about differential equations, about matrices and elliptic functions from his courses in vibrations, elasticity and design problems, and about vector analysis from his work in kinematics. However, we believe that Advanced Calculus should be a part of the Master's program in Applied Mechanics.

M.S. in Applied Mechanics

The difference between the Machine Design course and a program leading to a Master's Degree in Engineering Mechanics is the diversification of the former. While both include some of the same courses, the Engineering Mechanics program is a more specialized one. It would include a year of Advanced Calculus and one term each of Theory of Elasticity and Plasticity, and by all means a thesis. The Engineering Mechanics major is a specialist whom the machine designer among others consults when necessary. For him we propose the following:

1. *Advanced Calculus:* One year's work (2 semesters, 3 hours each) including a review of fundamentals, infinite series, Gamma, Beta and Bessel functions, introduction to vector analysis, complex variables and partial differential equations. Wood's "Advanced Calculus" is probably a suitable text.

2. *Vibration Problems:* A three or four hour course the same as the one recommended for the Machine Design man.

3. *Theory of Elasticity:* A three hour study of the mathematical theory of elasticity, general properties of stress tensor and strain tensor, two dimensional problems solved by Airy's function, elementary three dimensional problems, etc.

4. *Theory of Plasticity:* A three hour course covering the mathematical theory of plasticity; the laws of plastic flow, plastic flow in thick walled sphere and thick walled tube; plastic torsion, bending, etc.

5. *Thesis:* An individual research problem worthy of nine credit hours.

6. The remaining credit hours to be selected from such courses as—

Advanced Engineering Dynamics
Applied Elasticity
Experimental Stress Analysis
Theory of Plates and Shells.

Summary

We have shown that a Machine Designer is inherently a practical person who uses rather than discovers technical facts. Although he may be called upon to be both analyst and inventor, he is likely to be better at one than the other, and he has been in the business long enough to know which he prefers. We have shown too that graduate work is best suited to the needs of the analyst but that the type of analysis is diversified. Thus it is necessary for a mechanical designer to know something about a great many things, which distinguishes him from his close relative the "applied mechanics major" who knows a great deal about a few of the designer's problems.

**If thesis credit is given on an estimated time of $3 \times 15 = 45$ hours work per hour of credit, small problems could be assigned with credit from one hour up, and would include a written report. Only theses carrying six or more hours of credit would be bound and stored in the school library.

Discussion

By VENTON L. DOUGHTIE

Professor of Mechanical Engineering, University of Texas

I first would like to express my thanks to Professors Slaymaker and Wright for putting in print their ideas as to what "Graduate Work in Machine Design" should be. This is a topic which has many ramifications. To have found two people to co-author a paper on this subject is indeed a milestone in machine design education. I remember back in the early thirties when the late Professor F. L. Eidmann of Columbia University was editor of the *Machine Design Bulletin, Advanced Machine Design Courses* were considered for two years. All of us entered into the discussion, but no definite conclusions were reached.

For the most part I agree with Professors Slaymaker and Wright, but there are a few ideas which I would like to inject into the thinking. The authors' statements that, "Undergraduate Machine Design is the one subject which makes use of all previous courses" and "Subject-wise, the student meets nothing new in Machine Design. He simply applies what he has already learned" are well written. But I fear that our fellow staff members in Mechanical Engineering would not necessarily always agree to these statements. Often the Machine Design course is looked upon as a dull course in a drawing room where formulas and catalogues are used to obtain "a machine" so that the student can make drawings. In our design courses, the making of elaborate drawings has been reduced to a minimum, drawing-room equipment is used as a means of obtaining results, and experimentation is often necessary to get an essential machine element.

It would certainly be desirable for the graduate student in design to have some experience in this field before graduate study. I think any student would do better graduate work in any subject if he first had some experience; but those of us from state supported schools cannot prevent the student from continuing his graduate study immediately after receiving his baccalaureate degree. Therefore, a graduate course of study must be provided for this type of student. With the increased amount of knowledge apparently necessary for the young engineer, it might not be too far amiss for him to do graduate work in Machine Design immediately after obtaining his first degree. Most of the courses, which Professors Slaymaker and Wright suggest for graduate students in Machine Design, could be as well handled by the recent graduate as the individual who has spent some time in industry. Some phases of the work could be more easily mastered, because the recent graduate would have his fundamentals more readily in mind. Included in this group would be Vibration Problems, Advanced Strength of Materials, Dynamics of Machines, Applied Elasticity and Experimental Stress Analysis. The recent graduate could receive a great deal of benefit from the course, Problems in Machine Design, provided the course contained practical as well as theoretical applications. I would also like for the student to have courses in Physical Metallurgy, Servomechanisms and Production. It is probably true that ingenuity cannot be taught and that "know-how" is absolutely necessary, but I believe that a student who has the interest for graduate design study could and should be taught how things are made, tool and machine limitations, cost analysis, and how America makes a living. There is no substitute for practical experience, but a course on Production taught by a man with some production experience and a design background, can be beneficial to the person going into the design field.

I do not agree with the authors that course work may be substituted for a thesis. Perhaps this might be justified in the case of the person with considerable design experience. The library work in determining what is known about a subject gives the student essential training. The analysis of the problem to determine the factors involved, their interrelationship, and the procedure for test is design at its best. Planning the test set-up and building a part of it teaches such important lessons as: how it is constructed, whether or not it functions properly, can it be built economically, and is it better than other possible mechanisms designed for the same purpose. The experimentation, probably the first without a complete set of instructions, and the determination of the results will not only bring out the fact that theory and practice do not always agree, but that test results are sometimes unpredictable. Then finally the production of a thesis is an experience in the writing of an engineering report or technical publication that is invaluable. It takes time, and often there is not a definite contribution to the knowledge of the world, but sometimes negative results are useful. I believe six hours credit is sufficient for the master's thesis.

To briefly sum up my thoughts, (1) I would not limit graduate work in machine design to only those who had experience in design; (2) in addition to the analytical courses, I would include courses on Production, Metallurgy, and Servomechanisms; (3) in the so-called Advanced Machine Design Course, I would include some practical problems which would tease the student's ingenuity; and (4) I would require a thesis.

College Notes

Antonio Ferri, a pioneer in flight at speeds exceeding sound, who came to this country during World War II, to take part in the war effort under the auspices of the Office of Strategic Services of the U. S. War Department, has been appointed Professor of Aerodynamics at the **Polytechnic Institute of Brooklyn**, it was announced yesterday by Dr. Harry S. Rogers, president of the Institute.

. . .

A new professorship in metallurgical engineer has been established at **Carnegie Institute of Technology** through a grant from the Jones & Laughlin Steel Corporation, according to a joint announcement today by Carnegie President J. C. Warner and Admiral Ben Moreell, president of Jones & Laughlin. The new chair, supported by a grant of $15,000 per year, will be held by Dr. Gerhard J. Derge, professor of metallurgical engineering and a staff member of Carnegie's Metals Research Laboratory. Part of this sum will be used for research and equipment.

Mathematical Engineering Analysis

By RUFUS OLDENBURGER

Mathematician-engineer, Woodward Governor Company, Rockford, Illinois

Industry is placing increasing emphasis on engineering analysis, namely, the mathematical treatment of engineering problems. Engineering analysis involves the setting up of physical systems in the form of mathematical equations, generally differential equations, and the solution of these equations. The problem of solving the equations is the concern of many courses in mathematics and some of the newly created ones on computing machines. Many fine textbooks are available on these subjects, and they are often well taught. Instruction in the setting up of equations is a more difficult matter. Although this is one of the aims of any engineering curriculum, and the student will learn something about this from his regular engineering courses, the engineering graduate is generally ill equipped to step into industry and predict the performance of equipment, except for a few devices in which he has been especially trained. Thus the mechanical engineering graduate may know how to calculate the characteristics of a steam turbine of a particular type by methods worked out by others who were able to write down the equations, but may be completely at a loss to calculate the performance of a rocket for which equations have not been worked out by someone else, or for which a pattern of calculation has not been established. Even though the equations for a device have been worked out, one often does not have the time to look them up.

As labor and materials have become more expensive the necessity for analyzing equipment to avoid building something that will not work has increased considerably. Because engineering devices often involve components from all of the major fields of engineering, the engineer is being called on more and more to analyze components in other branches than his specialty. Thus an electrical engineer may design a solenoid valve for controlling gasoline flow, and will need to know some hydraulic theory to study the valve. Large manufacturing establishments may have a hundred or more people whose principle task is engineering analysis. These people are sometimes mathematicians and physicists, but more often engineers with a little more training in mathematics and physics than the average engineering graduate. Although large corporations can afford to have members who devote their entire time to engineering analysis, it is necessary for the average engineer concerned with research and development to make his own analyses. The demand for courses devoted entirely to this subject has therefore increased considerably in the last few years. For this reason the author introduced a four semester hour course in engineering analysis both at the Illinois Institute of Technology and De Paul University, designed for seniors and graduate students, along the lines to follow.

Although the subject deserves more attention than one course will allow, the tightness of present engineering schedules makes it advisable to begin a curriculum in engineering analysis with one course only, running over one semester. Although it is desirable for students to

have had some contact with differential equations and advanced calculus, these are by no means necessary since whatever the professor needs from these subjects he can supply, or will have to review anyway.

Course in Formulating Engineering Problems

A course in the setting up of engineering problems in mathematical form should have at least the following major objectives. First, as far as possible the student should be taught a logical, rigorous mathematical picture of the domains of engineering to be covered, so that the student will see just how the laws he uses to set up a particular problem fit into the basic theory of the field. In this way he can better appreciate the limitations of these laws, and select the ones to be applied.

Secondly, the student should be taught various principles for setting up equations. These principles are concerned with the technique of setting up equations, rather than the mathematical laws used. Such principles are often assumed implicitly by the analyst, but may not be obvious to the initiate. For example, if an analyst has set up his problem by neglecting certain factors, he can introduce these factors individually. If his results in each case are unchanged, he may suppose with confidence that if he introduced these factors simultaneously his results would be unchanged, whence his neglect of all of these factors in his initial analysis is justified. It is the author's experience that such principles can well be taught during the solution of practical problems so that these principles take on immediate everyday significance.

Thirdly, the student should be shown how a wide variety of frequently occurring practical problems are set up to a precision needed in industry. The equations so obtained should be as simple as possible because the efficient treatment of a problem generally implies the derivation of a simple set of equations whose solution can be obtained with a minimum amount of effort to no more accuracy than is required for the problem, or allowed when unknown factors are considered.

Division of Subject Matter

In a one semester course on the setting up of equations for physical systems it is not possible to cover all of the major branches of engineering. One solution is to treat the mechanics of particles and rigid bodies, fluid mechanics, heat, and electrical engineering. A possible division of subject matter is the following.

Mechanics—5 weeks (20 hours)

Mechanics of particles	1 hour
Mechanics of rigid bodies, especially linear motions	4 hours
General treatment of forces which occur in nature	1 hour
Review of ordinary linear differential equations	2 hours
Applications to engineering problems in linear motions and methods of making simplifying assumptions	4 hours
Theory of rotational motion about an axis	1 hour
Problems involving rotations, and combinations of linear and rotational motion	3 hours
General principles for setting up mechanics problems	1 hour
Dimensional analysis with applications to mechanics problems	3 hours

Fluid mechanics—3 weeks (12 hours)

Basic equations of fluid flow (force, continuity, and energy)	
Applications to flow of liquids (such as water)	4 hours
Theory and applications to aerodynamics	2 hours
General principles for setting up fluid mechanics problems	1 hour
Dimensional analysis applied to fluid problems	2 hours

Heat—3 weeks (12 hours)

Laws of thermodynamics	3 hours
Applications to thermodynamics problems (such as the flow of gases)	3 hours
Laws of heat transfer	2 hours

Applications of heat transfer theory	2 hours
General principles in the analysis of heat problems	1 hour
Dimensional analysis applied to heat problems	1 hour

Electricity and magnetism—3 weeks (12 hours)

Commonly applied laws (such as those of Kirchhoff for networks and Faraday for induced electromotive force)	5 hours
Applications to engineering problems	5 hours
General principles in the analysis of electrical and magnetic problems	1 hour
Dimensional analysis applied to electrical engineering problems	1 hour

The remainder of the course can be alloted to tests, discussion of problems, and the final examination.

The portion of the course devoted to mechanics can be given in a completely logical, rigorous manner, on the assumption that the student has the mathematical background in hand. Because mechanics is so basic to all engineering, and can easily be taught in a logical way, it is desirable to devote a fair portion of the course to this subject. Except for a few notions which must be borrowed from the theory of elasticity, the subject of fluid mechanics can also be taught in a completely logical manner in a reasonable amount of time. This is not true of the subjects of heat, electricity, and magnetism. Thus in heat transfer the proof of the Stefan-Boltzmann radiation law is much too involved to be included in the course. Further, it is not possible to treat properly the theory of electricity and magnetism in completely logical detail, and it will therefore be necessary to explain the meaning of the laws, and leave the details to be filled in by the student at his leisure.

In the course described above the professor can give the student some background in the rapidly developing field of engineering analysis, teaching him basic principles and giving him considerable practice in the setting up of a wide variety of engineering problems in mathematical form.

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ANNUAL MEETING

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Bibliodynamics Laboratory

By GEORGE S. BONN

Associate Librarian, The Rice Institute

The most expensive single piece of laboratory equipment in almost any engineering school in the country is its science-technology research library. Besides being expensive, it is relatively complex in theory, fairly complicated in construction, sometimes baffling in operation technique, frequently difficult in interpretation of results obtained, and always dangerous to misuse. It is a sensitive, though not necessarily a delicate, precision instrument—a well-designed and finely-engineered mechanism. Yet, how much real training in its use do students and research workers (and faculty, for that matter) get in the course of their college careers? Precious little, judging from information available in engineering college catalogs. (Columbia, of course, has been the perennial exception.)

A well-stacked research library with long runs of journals and an extensive collection of current reference books cannot be duplicated these days for much less than $15 a volume, all things considered. Just take a look at any of the periodical catalogs that are sent out from time to time by the various dealers in back sets of research journals, if you don't believe it. A pertinent example of cost might be this one: The median size of 31 engineering departmental libraries within university libraries, according to an Engineering School Libraries Survey in 1948–1949, was 13,000 volumes, and the sizes of the 31 libraries ranged from about 2000 to over 63,000 volumes. The replacement value of this median library today would be close to $195,000, no small sum in anybody's budget. And there are a good many excellent research libraries that are many times larger than this median departmental library.

Yet, every day scores of complete (or almost complete) novices, tyros, and fledgling research workers are turned loose on this expensive and defenseless piece of equipment in almost every school in the country.

Bibliocomplexes

There have been volumes written about the three-dimensional character of the inter-relationships between segments of the world's knowledge and about the problems of applying such a three-dimensional classification system to a two-dimensional book classification scheme so that books, in libraries for instance, can be shelved in a linear arrangement. There are volumes on the principles of cataloging books according to subject matter within this required two-dimensional system, just one of numerous cataloging problems confronted in every library.

Another time-consuming problem, both to the cataloger and to the subsequent library user, is the little matter of catalog entries. Briefly, the philosophy of cataloging is based largely on the admonition to render unto Caesar those things that are Caesar's; the only catch is in being mighty sure of your Caesar. For instance, the official journals, bulletins, transactions, proceedings, and the like of learned and professional societies are always cataloged (and listed) under the names of the societies, unless the publications have more distinctive titles. But most other publications come under their

given titles. A small point, perhaps, but knowing a little bit about the theory behind this apparent chicanery will save the library user many moments of maddening frustration. And there are other bibliocomplexes founded or confounded on what seems to be sheer caprice on the part of the librarians; these have a way of popping up at the most awkward times as the users of our libraries discover for themselves through nothing better than personal perseverance.

The very construction of the library presents difficulties to most users; not only the construction of the building itself but also the construction of the catalog and of the system for shelving periodicals, to mention a few. Older libraries have construction problems that are present in absolutely nothing else but in older libraries. For one thing, they all have edifice complexes. They are usually modeled after some Gothic pile, a chapel or an Old English dining hall or something else equally inspirational. There is hardly a functional stone in them and the one ray of light that slips in through each slim medallioned window does little to guide the weary searcher in his quest for truth. If the stacks are open and there is enough light to see by, the quester may find that bound periodicals have a shelving sequence entirely independent of everything else, based either on some alphabet or on the individual size of each journal. Even more recently-built libraries have the double standard in their shelving procedures, large volumes being arranged in a separate sequence from the one in which the ordinary-sized or small volumes are shelved. And the construction (or division or arrangement or what have you) of the card catalog, the real key to the library's treasures, is at times so baffling as to preclude even the most rudimentary search without some initiation into its mysteries.

Where to attack a room full of reference books, encyclopedias, handbooks, index services, abstract services, dictionaries, and several card catalogs is a decision that even the most hardy and ingenious soul at times finds difficult to make. Without an intelligent S.O.P. or more luck than might be reasonably expected, the hopeful novice is simply stopped in his tracks. Operation Killer seems tame in comparison with Operation Library, to our particular hero at any rate. Not knowing where to attack first our Don Quixote turns his lance on—yes, you guessed it—the person seated behind "the desk," the only one who looks at all official.

The neophyte seminar student or fledgling research worker tracking down references reminds one of nothing so much as a sad-eyed bloodhound. With 3 by 5 cards full of hieroglyphics, numbers, signs, letters, and punctuation marks, he tries his best to pin down the elusive bit of information he hopes to have verified. He surmises, he guesses, he cusses, he follows tips, he flips pages, he pounces upon clues until finally he wears out his patience and calls down a pox on the whole business. Getting a cardful of references to be unearthed is one matter, but interpreting them is quite another more often than not. Experience is, indeed, a hard master.

Now, it must be recognized that these bibliocomplexes and most others that library users come up against are part and parcel of any good science-technology research library that covers any appreciable portion of the world's knowledge, just as complex mechanisms and complicated scientific theories are part and parcel of any piece of laboratory equipment that is used for more than a foot rule. The tyro in any science or engineering lab is on a par with the novice in a science-technology library; both are confronted with what has come to be known as the innate cussedness of inanimate objects. Engineers are constantly working on the simplification of both machinery construction and machinery operation; so, too, are librarians working on the simplification of library construction and library operation. (Paradoxically, both engineers and librarians are build-

ing, at the same time, more and more complicated devices to do more and more complicated operations on more and more complicated problems that have arisen because of our ever-increasing accumulation of knowledge!)

Among the several purposes for laboratory instruction in one of the engineering departments at Northwestern University, for instance, are these: "To acquaint the student with machines and instruments and their use in engineering testing," and "To develop resourcefulness in setting up the apparatus, abstracting the pertinent data and drawing sound conclusions therefrom." In the first lab course in this department, some 50 per cent of the time is spent directly on instruments and testing, and another 20 per cent of the time on instrument and machine construction. In beginning courses in other engineering labs up to 60 per cent of the instructor's time is spent on instruction in the use of equipment and attendant ramifications. These same percentages hold true in many other schools, too, no doubt. In every case, intensive training is given the student at the time he most needs it: when he is first confronted with the problem of actually using the equipment for its intended purpose. It is then that the training is necessary both for the preservation of the equipment and for the education of the student; the training will sink in when the student appreciates its significance.

Bibliotechnical Training

It can be said with a great deal of truth that freshman English courses or freshman engineering-orientation lectures introduce the new students to the library. Unfortunately, however, the student has no continuing interest in the library more than that which might be required for him to write the term paper for English 101; the library, if it's a decently quiet and properly lighted one, becomes thereafter a place to: (1) study homework, (2) rest, (3) get dates, (4) read the newspaper, or, though rarely, (5) look at pictures in engineering magazines. Three or four years later after any inkling whatsoever of what the library can do for the student has long since disappeared, our junior or senior gets his comeupance in an undergraduate (or even graduate) seminar or a literature survey course. Having once heard about the library as a freshman he is turned loose in it with great expectations, but with what disastrous results.

And it can also be said with truth that many high schools have excellent library training in certain courses. So do they have excellent manual training and mechanical drawing and chemistry and physics courses and labs. But the difference between what the student gets in high school and what he gets in college is, to say the least, appreciable, even though the courses have similar subject approach. And the difference between a high school (or a branch public) library and a good science-technology library is also appreciable. It should be noted, though, that good library habits learned at the impressionable high school age seem to stand the student in good stead for quick assimilation of research library techniques later on.

It is true that most subject literature or seminar courses allow an hour or so on "the important sources of information" (or some such wording) in the particular field under consideration before the student is sent on his merry way. The results are about the same regardless of when the student gets his library briefing: the library staff gets each student individually and gives him just such information as the student wants for his immediate problem; the next time the same student will have a different problem, and the next time, and the next, *ad graduation*. These results are inevitable whenever the student becomes interested in a different, though related, field. However useful they are in keeping the library staff busy (and therefore happy because the statistics are going up) these results

are also flagrant evidences of inefficient use of the time of everybody concerned, the student, the instructor, and the library staff member.

There are some who may question the necessity or even the value of more than mere briefing in the proper use of a science-technology library for undergraduate students. If the purpose of engineering education is to turn out mere technicians, intelligent equipment operators, or brilliant slide-rule manipulators, then there is no point in spending more than a minimum time on library introduction. But if the purpose of engineering education is to give students a sound basis for furthering their own ambitions through continued study and interest in the field of engineering and to help students set patterns of scientific thinking that will be useful to them the rest of their lives, certainly they must be acquainted with and have respect for a good science-technology library and they must know how useful it can be in whatever field of work they find themselves.

It should be the purpose of any training in library usage first, to acquaint the student with the technical literature of engineering in general and of his own field in particular; second, to introduce the student to the literature of allied fields of science and to the literature of the social sciences and of the humanities; third, to prepare the student to make an efficient literature search; and fourth, to acquaint the student with the resources of his own engineering school library.

Instruction in the proper use of a piece of lab or research equipment is necessary so that the device may be put to the most efficient use for which it was intended. Machines that are expensive, hazardous, delicate, sensitive, complicated in theory, complicated in construction, complicated in operation technique, or complicated in the interpretation of results all require—and get—expert care and training in their operation. Why shouldn't the science-technology library which is, in its own way, just as needful of proper care and training in its use?

College Notes

Dr. Harry P. Hammond, Dean of the School of Engineering at the Pennsylvania State College, retired with emeritus rank on September 1 and was succeeded by Dr. Eric A. Walker, Director of the Ordnance Research Laboratory and Professor and Head of the Department of Electrical Engineering.

The research program in the School of Engineering made phenomenal gains during Dean Hammond's 14 years at Penn State, and today Penn State ranks among the leaders of all the institutions of the nation in funds budgeted for research conducted by its School of Engineering. Physical facilities of the School have also been expanded with the Electrical Engineering Building, which was started soon after Dean Hammond's appointment, completed in 1939, and the Civil Engineering Surveying camp constructed in 1940 and others.

During his years at Penn State, Dean Hammond won two of the top national engineering awards. In 1945, he was presented the Lamme Award, the top honor in the field of engineering education, while last year he was given the James H. McGraw Award in Technical Institute Education by the American Society for Engineering Education.

In World War II, Dean Hammond served as a member of the National Advisory Committee of Engineering Defense Training and was in charge of the

(*Continued on page 187*)

Thermodynamics for Graduate Students*

By ALI BULENT CAMBEL

Assistant Professor of Mechanical Engineering, State University of Iowa

Teaching advanced thermodynamics to graduate students is more difficult than teaching the basic discipline to undergraduates because for the former there are neither prescribed curricula nor standard texts. The instructor must be the sole and uncertain judge of what and how to teach future thermodynamicists.

In considering the problems involved in teaching of advanced thermodynamics, the first question which may be posed is: To what career does a graduate student specializing in thermodynamics look forward? Probably to scientific rather than production or maintenance work, either in an educational institution or in a research laboratory. The next question is: What is meant by scientific work in the field of thermodynamics? And the answer: Scientific work in thermodynamics is research and development leading to more economical or heretofore unknown conversions of thermal energy. The final question which may be asked is: Is there any need for research in thermodynamics? Definitely, yes. If we consider the depletion of our conventional fuels and resources, the needs of the atomic era, flight at great speeds and high altitudes, to say nothing of the intellectual challenges of the endless frontiers of science, we become convinced that there is definite need both for thermodynamic research and for the development of resourceful thermodynamicists who are able to execute such research development.

The initial training of future thermodynamicists takes place at the graduate level at which objectives for teaching are different from those for undergraduate instruction. In the teaching of thermodynamics to undergraduates the objective is to acquaint the student with fundamental laws and the standard applications of them. With graduate students, the purpose is not to repeat what has already been taught, but to deduce with them the various implications of the fundamental laws, to test the possibility of new applications of the laws, and to lead them to apprehend the logic of thermodynamics. Obviously, therefore, the teaching of future pioneers in thermodynamics will properly be more eclectic than dogmatic.

When the thermodynamicist does scientific work, investigating little known phenomena or developing new devices, how does he conduct his research? Either in some unorganized, trial-and-error way or in an organized and controlled manner. Undoubtedly the latter is preferable, because we can no longer afford to waste time, money, and human lives.

Organized research means, first, that which is based on analytical or empirical justification or on both. The research worker who does not know well the theory of his discipline can produce at best only mediocre work. Helmholtz advised, "There is nothing more practical than a good theory."

Second, organized research means that which is carried on methodically. Investigations in thermodynamics, as in any other field in which the frontiers of

*Presented before the Mechanical Engineering Division at the Annual Meeting of the ASEE, East Lansing, Michigan, June 27, 1951.

knowledge are to be pushed outward, must go through four stages. First, a general phenomenological knowledge of the possible events must be established from laboratory observations or from previous experience. Second, with this rough idea, an analysis should be made to formulate a mathematical expression of the phenomena. Third, this mathematical analysis must be experimentally proved. Many brilliant mathematical derivations do not truly represent the phenomenon described. Only a laboratory test of mathematical predictions can establish their validity. The design of the instrumentation for laboratory measurements as well as the measurements themselves will be determined by the mathematical analysis so the mathematics should be in a form that can be conveniently translated into a material state. Fourth, the data must be organized and from them a theory developed which is valid both mathematically and experimentally. Therefore, organized research in thermodynamics is based on sound justification and proceeds through a cycle of observation, formulation, measurement, and generalization. If this method of systematic study is inculcated into our graduate students we may expect to see some very fruitful work produced.

A Graduate Course in Thermodynamics

With the type and manner of work of the thermodynamicist defined, a method of preparing graduate students for such a career can be proposed. The three credit hours, one semester course which has been offered for the past two years in the Mechanical Engineering Department of the State University of Iowa is open only to graduate students who are working towards the master's or the doctor's degree. The prerequisites are undergraduate thermodynamics, fluid mechanics, and engineering mathematics.

Undergraduate courses in thermodynamics and fluid mechanics are clearly explained in the requirements of the ECPD, but "engineering mathematics" perhaps should be defined as a course beyond the calculus. Most institutions now require such a course, sometimes called "applied mathematics," which, though differing among institutions, usually includes ordinary and partial differential equations, theory of equations and vector analysis.

In our "Mathematical and Experimental Thermodynamics" the approach to thermodynamics is classical rather than statistical, because the mechanical engineer is concerned with macroscopic rather than microscopic systems. The material covered may be outlined in the sequence usually followed:

1. *The Concept of Temperature and the Zeroth Law.* The general mathematical expression for a thermometric scale is presented and the methods of constructing thermometers utilizing various thermometric properties are explained. The possible errors in thermometers are discussed and time lag is considered both analytically and physically. The course is started with thermometry because the student has dealt extensively with the use of thermometers and therefore he is at least on familiar ground when he is first asked to use mathematics and relate it to empirics.

2. *The Equation of State and Thermal Coefficients.* The technique of setting up state equations is demonstrated and the interrelationship of thermal coefficients is explained. It is indicated that thermodynamical coefficients are expressible by partial derivatives. Then the instrumentation necessary for the quantative measurement of these coefficients is described. On the basis of the difficulties of measurement encountered in instrumentation the suggestion is made that it is often convenient to transform an unknown thermal coefficient into one better known or one measured more easily than is the unknown coefficient itself.

3. *Dimensional Analysis.* Though dimensional analysis has been applied extensively in heat transfer and fluid flow, its potentialities have not been fully ex-

ploited in the field of thermodynamics. For instance, work on the applying of the principles of similitude in the designing of internal combustion engines is already being carried on in several institutions. Therefore, this study is very practical. Furthermore, the teaching of dimensional analysis manifests the difference between equations in applied mathematics and those in pure mathematics. Further, it is emphasized that the number of dimensionless products is not necessarily equal to the number of derived units minus the number of fundamental limits.

4. *The Line Integral.* The difference between path functions and point functions is demonstrated and a study is made of the theorems which indicate how a thermodynamical function may be tested for independence of its path. In studying the appropriate theorems their necessary and sufficient conditions are proved, so that the student achieves a better grasp of the mathematical approach to thermodynamics.

5. *The First Fundamental Law.* The first law is approached in accordance with the Poincaré view. This may have been expected from the study of the Zeroth Law. The mathematical necessity for the existence of internal energy is proved, and its being a point function is demonstrated. The fact that the steady flow energy equation is a consequence of the first law and that the first law is not derived from the steady flow equation is particularly emphasized. The enthalpy is introduced and various relations for computing it from other thermal coefficients are derived.

6. *The Second Law of Thermodynamics.* Kelvin's temperature scale is explained and then Clausius' theorem is used to demonstrate that the entropy is a mathematical necessity because it becomes apparent when an integrating factor is found in the converting of an inexact to an exact differential. Relations are developed to define the entropy in terms of quantities which are directly measureable, thus familiarizing the student with the development of thermodynamic tables. The free energy functions of Helmholtz and Gibbs and Planck are discussed in some detail, and it is shown that, like the entropy, they are criteria of equilibrium.

7. *The Third Law of Thermodynamics.* Although Nernst's heat theorem has reached the status of a thermodynamic law it is rather difficult to convince students by means of classical thermodynamics that the integration constant of the entropy differential should be zero at absolute zero. In explaining the third law the approach of Lewis and Randall is followed.

8. *Thermodynamic Functions.* The Maxwell equations are derived both by the method of partial differential equations and by that of analytical geometry.

9. *Functional Determinants.* The fundamental theorems of the Jacobians are proved. It is showed that these must be obeyed in the writing of an equation of state or the unequivocal determination of a thermodynamic state point. Norman Shaw's Jacobian method in the manipulation of thermodynamic equations is discussed and the resulting relations are discussed from the point of view of ease of experimental determination.

10. *Thermodynamics of Fluid Flow.* Vectorial analysis is presented as the thermodynamicist's best technique for investigating fluid flow. The discussion is based on the Eulerian system thus immediately restricting it to isentropic flow. It is showed, for example, that for irrotational flow the entropy must remain a constant. Furthermore, it is indicated that for supersonic flow the characteristic equation must be expressed in hyperbolic form.

11. *Gas Dynamics.* The thermodynamics of gases at high velocities is discussed on the basis of the energy equation, by which losses may be accounted for. The Fanno conditions, the Rayleigh conditions, and shock phenomena are considered. The measurement of flow

quantities by the stagnation tube and the Toepler-Schlieren method are studied as the final topics in the course.

General Comments

To this topical outline of "Mathematical and Experimental Thermodynamics" should be added some general comments:

1. The instruction is not an attempt to teach thermodynamics nor mathematics nor instrumentation, but to show the mathematical and experimental techniques available to the research thermodynamicist.

2. The instruction attempts logically to develop in the student an understanding of thermodynamics by the emphasizing of the interrelation between mathematics and experimentation. The approach is fundamentally mathematical. There is no more simple nor more uninhibited approach to thermodynamic research than that of mathematics. However, experimental checking is continually urged as a salutary rein on the enthusiasm of the theorist. In a crude analogy, mathematics is comparable with the vigor of youth, and instrumentation with the wisdom of experience and maturity. In conjunction, mathematics and instrumentation make up a powerful team; separately, they achieve little.

3. The instruction indicates to the student some of the present limitations of classical thermodynamics and urges that he become familiar with Kinetic Theory and Statistical Thermodynamics. On the other hand it becomes evident that the science of thermodynamics is far from having been exhaustively investigated.

4. By presenting research methods the instruction makes it possible for the advanced student writing a thesis to spend less time developing his techniques and more gathering and interpreting his data.

5. To future teachers of thermodynamics the instruction imparts an insight which can be achieved only by a philosophical approach.

6. No attempt is made to give a physical meaning to mathematical functions like the enthalpy, the entropy and the free energies. However, their importance in studying physical effects is discussed.

7. Research requires the drawing of correct conclusions from feasible assumptions. In other words, it rests on syllogisms which in engineering research are represented by mathematical relations.

This course was instituted to transform graduate students into thermodynamicists who are prepared for their jobs and who can work at them efficiently. The content and methodology grew out of a consideration of the kind of work and the proper method of procedure of a scientist in thermodynamics.

ANNUAL MEETING

June 23–27, 1952

Dartmouth College **Hanover, N.H.**

THE T-SQUARE PAGE

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J. S. RISING
H. E. GRANT
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DEVOTED TO THE INTERESTS OF ENGINEERING DRAWING

B. L. WELLMAN, *Editor*
Worcester Polytechnic Institute

Officers
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J. G. MCGUIRE
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Mid-Winter Drawing Division Program
New York City, January 23, 24 and 25, 1952

The Executive Committee has accepted the invitation of three New York universities to hold the Mid-Winter Meeting of the Drawing Division in that city in January, 1952. The tentative program is as follows:

Wednesday, January 23, 1952
AT THE COOPER UNION

Morning

8:30–10:00 Registration.
Inspection of Department of Machine Design and Engineering Drawing.
Tour of Historic Foundation Building of The Cooper Union for those who desire it.

10:00–12:00 Meeting.
Greetings, Dr. Edwin S. Burdell, President of The Cooper Union.
Welcome from the Engineering School, Dean Norman L. Towle.
Response, Professor Clifford H. Springer, Division Chairman.
"Descriptive Geometry in Ship-building." Mr. Renato Iodice, Naval Architect, Gulf Oil Company, Part-time Instructor, The Cooper Union Evening School.

12:00 Luncheon.

Afternoon

1:00–1:20 Board bus for New York Naval Shipyard.

2:00–4:15 New York Naval Shipyard.
Greetings, Rear Admiral P. B. Nibecker, Commander, New York Naval Shipyard and Naval Base.
Demonstration and Explanation of Lofting in the Mold Loft (developing a shell plate), Lieutenant (S.G.) Dixon, assisted by a loftsman.
Visit to Plate Shop, direction of Commander Fink.
Visit to Dry Docks (if time and weather permit).

5:00 Arrive at The Cooper Union
Open House.

Evening Executive Committee Dinner.

Women's Program
Tours of New York City, visits to Museums and Art Galleries, shopping, luncheon.

Thursday, January 24, 1952
at THE UNITED STATES MILITARY ACADEMY
West Point, N. Y.

Morning

8:30 Leave New York by special bus.

10:30 Arrive at West Point.

11:00–1:00 Men's Program, in Department of Military Topography and Graphics.
1. The mission of West Point.
2. The over-all curriculum and its effect on fulfilling this mission.
3. The part played by the Department of Military Topography and Graphics in in this curriculum.
4. Demonstration of methods used.
5. Exhibition of facilities, teaching aids, etc.

Women's Program

Conducted tour of kitchens, bakeries, cadet mess hall and museum, as time permits.

Afternoon

1:00 Luncheon at Hotel Thayer (both men and women).

2:00–4:00 Conducted tour of West Point Reservation, concluding with a short organ recital in the Cadet Chapel (men and women).

3:00–4:00 Opportunity for members to meet friends or relatives in the Cadet Corps.

4:00–6:00 Return to New York City.

Evening Theatre party. Efforts are being made to reserve a block of tickets for a musical show.

Friday, January 25, 1952
at COLUMBIA UNIVERSITY

Men's Program

Morning

9:00 Inspection of Department of Graphics, 6th floor, Eng. Bldg.

10:30 At Harkness Academic Theatre.
"The Integration of Drafting with the Photographic Process," Lloyd E. Varden, Technical Director, Pavelle Color, Inc.
Discussion.
Second paper to be announced.

12:30 Luncheon. John Jay Hall Mezzanine.

Afternoon

2:00 Trip 1. Special bus to "Nevis." Inspection of the Columbia University Cyclotron.
Trip 2. Inspection of the photographic color processing plant of Pavelle Color, Inc.

Evening Annual Dinner, Men's Faculty Club, Columbia University.
Speaker: Dr. John R. Dunning, Dean of the School of Engineering, Columbia University.

Women's Program

Morning Guides will be provided for shopping or sight-seeing. Television color broadcast.

Afternoon

1:00 Luncheon.

2:00 Style Show.

3:00 Choice of following trips:
1. Behind-the-scene trip through Vogue publishing offices.
2. Good Housekeeping Institute.
3. McCall Home-Maker Institute.
4. Costume Institute, Metropolitan Museum of Art.

ANNUAL MEETING

June 23–27, 1952

Dartmouth College **Hanover, N.H.**

TIMELY TIPS

Problems Relating to Rolling With Slipping

By S. R. UNIECHOWSKI

Assistant Professor of Engineering Mechanics, University of Detroit

The majority of text-books in Engineering Mechanics in this country, while giving a good selection of problems on rolling without slipping, fail to explain in an adequate manner the method of solution when sliding does occur or is suspected.

The statement: . . . "A homogeneous cylinder (or wheel, or sphere) of radius r rolls without slipping . . ." is taken by the students for granted nearly in the same way as for instance the fact that all bodies in Mechanics are considered to be rigid.

A. Pure Rolling

A homogeneous body (cylinder, wheel, disc or sphere) rolls down a rough inclined plane without sliding. Find the distance travelled in t seconds from rest. Suppose that, at the beginning of the motion, B was in contact with A. C is the point of contact t seconds after the start. Let AC be denoted by x and let r be the radius. Let N by the normal pressure between the body and the plane and F the frictional resistance up the plane. The equations of motion of the mass-center of the body will be:

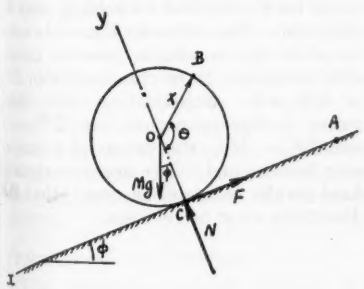

FIG. 1.

$$\Sigma F_x = M\bar{a}_x;\ Mg\sin\phi - F = M\bar{a}_x, \quad (1)$$

$$\Sigma F_y = M\bar{a}_y;\ Mg\cos\phi - N = 0, \quad (2)$$

$$\Sigma T = I\alpha;\ rF = I\alpha. \quad (3)$$

Since there is no sliding AC is equal to the arc BC; that is

$$X = r\theta. \quad (4)$$

Differentiating both sides twice, we get

$$\frac{d^2x}{dt^2} = \bar{a}_x = r\cdot\frac{d^2\theta}{dt^2} = r\alpha. \quad (5)$$

Eliminating F from (1) and (3)

$$M(r\bar{a}_x + K^2\alpha) = Mrg\sin\phi. \quad (6)$$

From (5) and (6)

$$\bar{a}_x = \frac{r^2}{r^2 + K^2}\cdot g\sin\phi. \quad (7)$$

Integrating twice the last equation the distance travelled in t seconds from rest is thus

$$X = \frac{r^2}{2(r^2 + K^2)}\cdot gt^2\sin\phi. \quad (8)$$

Equation (1) gives now the friction. Thus

$$F = Mg\sin\phi - M\bar{a}_x$$

$$= \frac{K^2}{r^2 + K^2}\cdot Mg\sin\phi. \quad (9)$$

B. Rolling and Sliding

A homogeneous body (as in "*A*") rolls and slips down a rough inclined plane. Find the acceleration down the plane $\bar{a}_x$ and the angular acceleration.

When the body is rolling and sliding *the friction is limiting friction.*

The equations (1), (2) and (3) of part "*A*" are still valid. But since slipping takes place the equation (4) is no longer true. Instead we have the equation expressing the fact that the friction is limiting friction.

$$F = \mu_K N, \tag{4}$$

where μ_K is the coefficient of *Kinetic* friction. From equation (2)

$$\mu_K N = \mu_K M g \cos\phi. \tag{5}$$

Substituting this value for F in (1) and (3) and then dividing each by M

$$\bar{a}_x = g \sin\phi - \mu_K g \cos\phi, \tag{6}$$

$$K^2\alpha = \mu_K a g \cos\phi. \tag{7}$$

Thus both the acceleration of the mass-center $\bar{a}_x$ and the angular acceleration α are constant. The motion of the mass-center is entirely independent of the shape of the body when slipping does occur.

The equation (6) is just the same for a body which does not roll at all.

C. Test for Slipping when a Body (as in "A") Rolls Down a Rough Inclined Plane

When a body rolls down a rough inclined plane the motion may be pure rolling or a combination of rolling and sliding and both sorts of motion have to be investigated. Equations (2) and (7) of part "*A*" give

$$\frac{F}{N} = \frac{K^2}{r^2 + K^2} \cdot \tan\phi. \tag{1}$$

But F cannot be greater than $\mu_S N$. Consequently the motion will be a combination of rolling and sliding if

$$\frac{K^2}{r^2 + K^2} \cdot \tan\phi > \mu_S, \tag{2}$$

and will be pure rolling if

$$\frac{K^2}{r^2 + K^2} \cdot \tan\phi < \mu_S, \tag{3}$$

where μ_S is the coefficient of *static* friction.

Before attempting to solve the equations of motion for a body rolling down a plane, it will therefore be necessary to discover which of the inequalities (2) or (3) is true. If (2) is true the results of part "*A*" are correct, but if (3) is true the results of "*B*" must be used.

When sliding occurs the instantaneous center is not at the point of contact C but on the line OC below or above the plane at a distance R from O, such that

$$\bar{a}_x = R\alpha \quad \text{or} \quad R = \frac{\bar{a}_x}{\alpha}$$

($\bar{a}_x$ being now *not* equal to $r\alpha$).

General Remarks

In problems where in addition to the weight of the body other external forces are involved the whole procedure of solution is slightly different.

The direction of the frictional resistance must be assumed first and from the equations $\Sigma F_x = M\bar{a}_x$ and $\Sigma \bar{T} = I\alpha$ the value for F, required for rolling, may be obtained. This value for F must be compared to the maximum possible (available) frictional force obtained from $\Sigma F_y = M\bar{a}_y = 0$. Substituting the later value, if slipping occurs, into $\Sigma \bar{T} = I\alpha$ and $\Sigma F_x = M\bar{a}_x$, the values of α and $\bar{a}_x$ may be obtained. The negative signs in final results indicate, as usual, that the directions must be reversed.

Minutes of Executive Board Meeting

A meeting of the Executive Board of The American Society for Engineering Education was held on Saturday, September 29, 1951, at Cornell University, Ithaca, New York. Those present were: S. C. Hollister, *President,* M. M. Boring, A. B. Bronwell, L. E. Grinter, J. H. Lampe, G. A. Rosselot, C. L. Skelley, and B. Bowen. The meeting was called to order at 9:30 A.M.

Report of the Treasurer:

The report of the Treasurer was presented. Receipts and disbursements were reviewed in the period of July 1 to September 30, 1951 as compared with the first quarter of last year.

Vice President Lampe reported on the plans for the ECAC meeting. The two major topics to be discussed are: (1) adequacy and standards of engineering education, and (2) cooperation between junior colleges, secondary schools, and colleges in matters relating to educational standards, guidance, etc. He requested President Hollister to handle the first topic and will secure speakers for the second topic.

Vice President Rosselot reported that the ECRC has been studying the problem of contract relations with the federal government since June. There have been active conferences in Washington on such matters as equipment procurement problems, contract regulations, patents, etc. The ECRC is attempting to formulate a sound policy embodying desirable features of contract relationships between the federal government and engineering colleges. These problems will constitute the program material for the Houston meeting.

Improvement of Teaching:

Vice President Grinter reported that the Committee on Improvement of Teaching has sent a preliminary report to the chairmen of institutional committees and deans of engineering colleges, asking for comments and criticisms. A small writing committee will be appointed to prepare a final report to be presented at the Annual Meeting at Dartmouth. The Committee is working with the Division of Educational Methods so that in the future the work can be carried on by this Division.

Unity of the Profession:

Dean Saville has requested specific recommendations from the Society on the proposed plans for a Unity of the Profession Organization. At the June 29 meeting of the General Council a motion was passed to the effect that the ASEE should be included in any unity organization and that the Society should cooperate fully in the formation of such an organization, provided that the ASEE as a constituent society can retain its present membership requirements. However, this resolution was not definitive enough to enable Dean Saville to present the recommendations of the ASEE as to the structure of the unity organization. After considering the four proposals prepared by the EJC Committee on Unity of the Profession, the Executive Board expressed preference for some type of organization which would combine the desirable features of Plans A and B. In general, the Council type of organization seemed to be preferred over the individual membership type of organization.

Joint Committees with Organizations of Junior College and Secondary School Principals and Counselors:

President Hollister proposed that the ASEE take steps to set up a joint committee enabling the junior college faculties, high school principals, and voca-

tional counselors to participate with the Society in discussions of problems relating to the adequate preparation of engineering students. He stated that the ASEE could lay the groundwork for real cooperation between engineering colleges, junior colleges and high schools. As a means of initiating this program, it was proposed that three people be invited to attend the Houston meeting for active participation: a member of the Science Teachers Association, a member of the High School Principals Association, and one person from the Edison Educational Foundation. Invitations will also be extended to Admiral Bowen and Mr. Paul Busse of the Edison Foundation to attend the ASEE meetings in Houston.

The Secretary mentioned that a Junior College Committee has not yet been appointed. It was decided to defer appointment of this Committee until the new program of cooperation with Junior Colleges and Secondary Schools has been clarified. It was pointed out that since the Secondary Schools Committee is a Committee of the ECAC, it might be logical to have the Junior College Committee also report to the ECAC.

Suggestions from Society Members for Consideration by the Council:

The Executive Board decided to appoint a committee of members of the General Council to study the problem of setting up a mechanism for more active participation by Society members.

Mailing of American Council on Education Bulletins:

The question was raised as to whether or not the Society should continue to subsidize mailing of American Council on Education bulletins to engineering deans. It was decided to continue this mailing.

Mission on Engineering Education to Japan:

Secretary Bronwell outlined briefly the work of the Mission on Engineering Education to Japan during the past summer. The fifteen members of the Mission, under the chairmanship of Harold Hazen, held meetings in educational centers throughout Japan. The meetings were in the form of panel discussions, with U. S. and Japanese representatives on the same panel. Over 1000 Japanese educators participated in these discussions.

The panel discussions dealt with administrative problems, research policies, cooperation between industry and colleges, improvement of teaching, and specialized topics in various curricular areas. The panel discussion system proved to be very successful in focusing attention upon those problems which were of greatest importance to the Japanese.

The Secretary commented favorably on the progress which is being made in research in engineering colleges and pointed out some of the problems in their educational system, many of which are quite similar to problems in American engineering colleges. A proposal has been made to set up a society for engineering education in Japan comparable to the ASEE. The Secretary stated that extremely cordial hospitality had been accorded members of the Mission by the Japanese educators and that the Mission has served to develop working relationships between Japanese and American educators, as well as a common bond of friendship.

Other Missions on Research and Engineering Education:

It was pointed out that several missions on research and education are being organized to visit European countries. The Executive Board expressed the opinion that the ASEE should be officially represented on these missions. Dr. Rosselot and Dr. Grinter will confer with the proper authorities on methods of getting ASEE representatives appointed to these missions.

Summer School Requests:

The Board approved the requests of the Electrical Engineering Division and

the English Division for summer schools to be held at Dartmouth in June. Details of planning of these two summer schools should be arranged with Dean Kimball by the Divisions themselves. Mr. Boring mentioned that the General Electric Company would like to sponsor a "Methods of Instruction" program during the week after the Annual Meeting at Schenectady in order to familiarize educators with some of the novel methods of instruction used in the company's post-graduate program. The Executive Board approved this plan, details of which will be worked out by Mr. Boring.

Organization of Textile Committee:

The Secretary read a letter from Professor Rogers Finch of M.I.T. suggesting the possibility of the organization of a Committee on Textile Engineering in the ASEE. A motion recommending the formation of such a committee was approved.

Associate Institutional Membership Drive:

President Hollister stated that Mr. Jesse McKeon had been appointed chairman of a committee to approach those industries which are interested in engineering education in order to expand the number of associate institutional members. Mr. McKeon is now getting this project organized.

Respectfully submitted,

ARTHUR BRONWELL,
Secretary

College Notes

(*Continued from page 176*)

inspection of Army Specialized Training Program units in the Third Service Command.

From 1924 to 1927, Dean Hammond was associate director of a comprehensive study known as the "Investigation of Engineering Education," which was sponsored by the ASEE. He was an active member of the ASEE, serving as Vice-President in 1934–35 and as President in 1936–37. He was one of the organizers of the Engineers' Council for Professional Development and also helped to organize and served until last year as Chairman of the Council's Committee on Technical Institutes.

Dr. Walker during the period 1942 to 1945 served as research associate, assistant director, and finally associate director of the Harvard Underwater Sound Laboratory, Cambridge, Mass., where he had charge of the development of ordnance weapons. For his work there, he was awarded the Naval Ordnance Development Award and also a Presidential Certificate of Merit.

In 1945, through the efforts of Dr. Walker and Dean Hammond, arrangements between the College and the Bureau of Ordnance, Navy Department, were completed, establishing the Ordnance Research Laboratory at Penn State. Work in the laboratory started on October 1, 1945, and many of the staff members, including Dr. Walker, came to Penn State from the Harvard Underwater Sound Laboratory. Dr. Walker has served as Director of the Laboratory from its founding and at the same time has held the position of Professor and Head of the Department of Electrical Engineering.

Dr. Walker, who was elected last year as a director of the ECRC, has also served as Chairman of the Educational Methods Division of the ASEE.

Section Meetings

Section	*Location of Meeting*	*Dates*	*Chairman of Section*
*Allegheny	Carnegie Institute		E. B. Stavely, Pennsylvania State College
Illinois-Indiana	University of Illinois	May 17, 1952	D. G. Ryan, University of Illinois
Kansas-Nebraska	University of Nebraska	Nov. 16–17, 1951	Kenneth Rose, University of Kansas
Michigan	University of Detroit	May 10, 1952	W. P. Godfrey, University of Detroit
Middle Atlantic	Newark College of Engineering	December, 1951	S. J. Tracy, Jr., City College of New York
Missouri	University of Arkansas	April 5 or 12, 1952	R. Z. Williams, Missouri School of Mines
*National Capital Area			W. Oncken, Jr., Bureau of Ordnance
*New England			W. C. White, Northeastern University
*North Midwest			K. F. Wendt, University of Wisconsin
*Ohio	Ohio State University		W. F. Brown, University of Toledo
*Pacific Northwest	Seattle		T. H. Campbell, University of Washington
*Pacific Southwest	Los Angeles San Francisco	April, 1952	S. F. Duncan, University of Southern California
*Rocky Mountain	University of Wyoming		E. J. Lindahl, University of Wyoming
Southeastern	Clemson College	April 10, 11, 12, 1952.	R. L. Sumwalt, University of South Carolina
Southwestern	University of Houston	April 11 & 12, 1952	H. P. Adams, Oklahoma A. & M. College
*Upper New York	Clarkson College		W. H. Allison, Clarkson College

Members of the Society are welcome at all Section Meetings

* No Date Set.

New Members

BLAKEMORE, WYATT D., Instructor in Engineering Drawing, Iowa State College, Ames, Iowa. A. S. Gaskell, S. J. Chamberlain.

BLISARD, THOMAS J., Associate Professor of Physics, Newark College of Engineering, Newark, N. J. C. V. Bertsch, H. H. Smith.

BOWMAN, JOHN J., Director, Bowman Technical School, Lancaster, Pa. K. O. Werwath, S. A. Eng.

BRILL, KENNETH G., JR., Associate Professor of Geology and Geological Engineering, St. Louis University, St. Louis, Mo. R. R. Heinrich, J. B. Macelwane.

BROOKS, EDWARD M., Associate Professor of Geophysics and Geophysical Engineering, St. Louis University, St. Louis, Mo. R. R. Heinrich, J. B. Macelwane.

BUBB, FRANK W., JR., Associate Professor of Engineering, St. Louis University, St. Louis, Mo. R. R. Heinrich, J. B. Macelwane.

BURGER, WILLIAM V., Registrar, Colorado School of Mines, Golden, Colo. F. R. Campbell, G. W. LeMaire.

CLARK, RODERICK D. M., Instructor in Geophysics and Geophysical Engineering, St. Louis University, St. Louis, Mo. R. R. Heinrich, J. B. Macelwane.

COYLE, FRANK J., Associate, Bureau of Trade and Technical Education, N. Y. State Dept. of Education, Albany, N. Y. W. H. Branch, F. E. Almstead.

CREELMAN, GEORGE D., Research Coordinator, M. A. Hanna Company, Cleveland, Ohio. C. E. MacQuigg, L. D. Jones.

CRONIN, JAMES L., JR., Assistant Professor of Engineering, St. Louis University, St. Louis, Mo. R. R. Heinrich, J. B. Macelwane.

CROWNINSHIELD, WILLIAM W., Head, Mechanical Dept., Franklin Technical Institute, Boston, Mass. R. G. Adams, P. H. Humphries.

DAVIS, CHARLES R., Professor of English, Rutgers University, New Brunswick, N. J. E. C. Easton, M. T. Ayers.

DAVIS, JOHN F., Instructor in Electrical Engineering, University of New Mexico, Albuquerque, N. M. M .E. Van Valkenburg, W. G. Hoover.

DESOUSA, JOSE CARLOS C., Graduate Student, University of Michigan, Ann Arbor, Mich. G. W. Clark, N. S. Waner.

DREIFKE, GERALD E., Assistant Professor of Engineering, St. Louis University, St. Louis, Mo. R. R. Heinrich, J. B. Macelwane.

FEIGEN, MORRIS, Associate Engineer, Engineering Dept., University of California, Los Angeles, Calif. C. M. Duke, J. M. English.

FELDMAN, EDWARD S., Instructor, University of California, Los Angeles, Calif. C. M. Duke, J. C. Dillon.

FULLER, H. EDWARD, Instructor in Electrical Engineering, Franklin Technical Institute, Boston, Mass. R. G. Adams, B. K. Thorogood.

HUFF, WILBERT J., Professor and Chairman of Chemical Engineering, University of Maryland, College Park, Md. S. S. Steinberg, R. B. Allen.

HUNT, ROY E., Technical Recruiting Division, General Electric Company, Schenectady, N. Y. C. F. Terwilliger, K. B. McEachron, Jr.

JOHNSON, CHARLES A., Assistant Professor of Mathematics, Missouri School of Mines, Rolla, Mo. R. M. Rankin, R. H. Kerr.

KIMBALL, LEE E., Assistant Professor of Engineering, St. Louis University, St. Louis, Mo. R. R. Heinrich, J. B. Macelwane.

KISSLINGER, CARL, Instructor in Geophysics and Geophysical Engineering, St. Louis University, St. Louis, Mo. R. R. Heinrich, J. B. Macelwane.

KYBURZ, PAUL H., Instructor in Mechanical Engineering, Michigan State College, East Lansing, Mich. C. C. Sigerfoos, H. L. Womochel.

MARSHALL, STANLEY C., Assistant to Director, Penn Technical Institute, Pittsburgh, Pa. N. P. Bosted, L. A. Dimasi.

McBRIDE, GUY T. ,Assistant Professor of Chemical Engineering, Associate Dean of Students, The Rice Institute, Houston, Texas, W. V. Houston, L. B. Ryon.

McMANUS, JOHN F., Assistant to the Dean, Cornell University, Ithaca, N. Y. W. L. Conwell, R. F. Chamberlain.

MILLER, HOWARD M., Personnel Consultant, Engineering Dept., E. I. duPont de Nemours & Company, Wilmington, Del. R. L. Sumwalt, L. E. Grinter.

PANLENER, GLENN F., Assistant Professor of Mechanical Engineering, New Mexico College of A. & M. A., Las Cruces, N. M. M. A. Thomas, R. E. James.

PILOTTE, FRANK F., Instructor in Geophysics and Geophysical Engineering, St. Louis University, St. Louis, Mo. R. R. Heinrich, J. B. Macelwane.

POTTER, CLARK A., Instructor in Engineering, St. Louis University, St. Louis, Mo. R. R. Heinrich, J. B. Macelwane.

REICKERT, FREDERICK A., Associate Professor of Civil Engineering, University of Illinois, Urbana, Ill. J. C. Dietz, T. C. Shedd.

RICE, WARREN, Instructor in Mechanical Engineering, A. & M. College of Texas, College Station, Texas. R. M. Wingren, R. V. Jarvi.

RICHARDS, CEDRIC W., Instructor in Civil Engineering, Stanford University, Stanford, Calif. E. L. Grant, H. A. Williams.

RUSSELL, ARTHUR L., Head of Electrical Dept., Franklin Technical Institute, Boston, Mass. R. G. Adams, P. H. Humphries.

SHAUGHNESSY, THOMAS E., Deputy for Education, The Ordnance School, Aberdeen, P. G., Md. D. C. Jackson, Jr., F. E. Roediger.

SPENCE, DAVID W., Instructor in Electrical Engineering, Syracuse University, Syracuse, N. Y. S. Seely, R. A. Galbraith.

STRUM, ROBERT D., Instructor in Electrical Engineering, Rose Polytechnic Institute, Terre Haute, Indiana. C. C. Knipmeyer, R. M. Ross.

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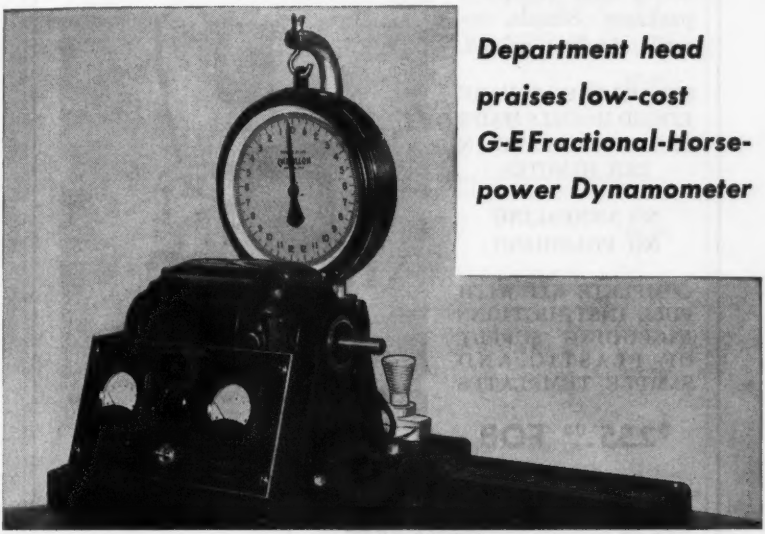

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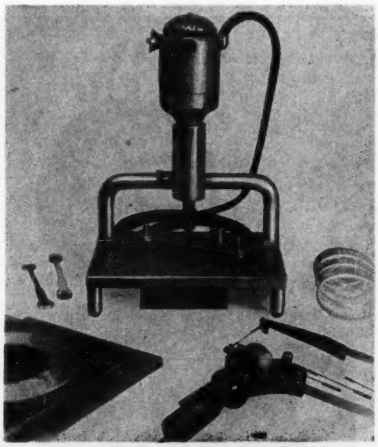

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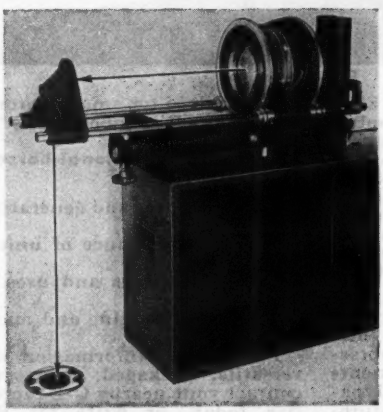

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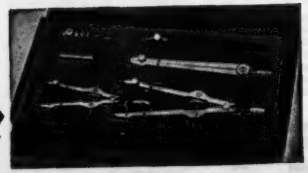

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